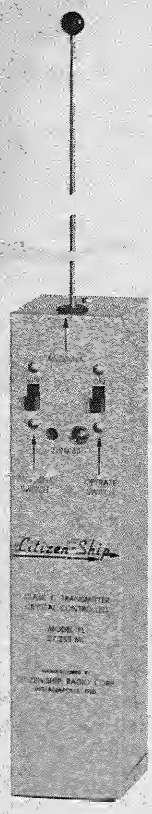


Typical transistorized hand-held single-channel transmitter popular with beginners and sport fliers.

1-1 **This electric-powered boat, equipped with dual proportional control, is steered by means of the wheel seen in the boy's right hand.**

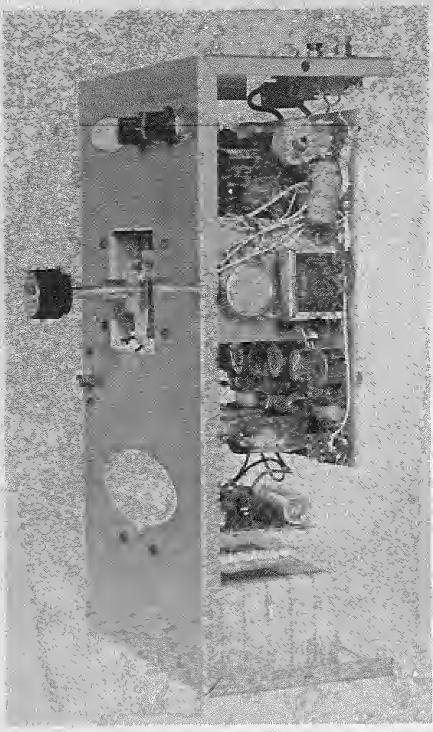
such as an airplane. An electric-powered boat or car, etc., puts less premium on operational skill. The operator's skill and experience are as much a part of the system as either the vehicle or the radio. The over-all system—man, radio, vehicle—should be matched for optimum success. (Depending on whether the vehicle is airborne, marine or ground operated, items within a system vary greatly.)

The human element is remarkably variable. For some kinds of models, prior experience in more or less similar, although not necessarily R/C, models greatly enhances prospects. For others, such experience is less unimportant. If truly expert advice and help is available to you, you can do more with less experience than would otherwise be possible.

1-2 **Typical multichannel transmitter and receiver. Control sticks on right side of transmitter are for rudder and aileron; those on left, for engine, elevator and elevator trim. At right side of receiver is the reed bank, individual reeds vibrating to close servo contacts when appropriate tones are transmitted.**

The number of controls which the operator wishes to incorporate obviously influences the amount of the working time and the difficulty of operation. Since operating skill is related to the type of vehicle, biting off more than one can chew as a beginner may easily result in damage or loss of model (if an airplane) and its contained equipment. Or the vehicle may not satisfactorily attain the operational stage.

Before we can evaluate possibilities of various kinds of models, it would be good to understand the significance of the word "channel," which will be encountered frequently. Simply expressed, a channel can be considered a direct radio link between any kind of transmitting keying switch or device which causes a signal (or signals) to be sent and an actuator (or actuators) to be activated (via a receiver) within the vehicle. For example, when a keying pushbutton or microswitch is closed or depressed at the transmitter, a rudder surface on an airplane or boat can be moved to a control position. Or the turn of a steering wheel on a transmitter control box may



1-3 **A single-control-stick multichannel proportional transmitter, case removed to show printed circuit board mounting of parts. Nickel-cadmium batteries at bottom, power converter just above them.**

cause a boat rudder, or an auto's front wheels, to assume a turn position. (Fig. 1-1.) Or the application of a transmitter lever switch will move an airplane elevator up or down. Regardless of the type of switching arrangement on a transmitter — or on a control box, or keying lead of any kind, linked with the transmitter—activating a device directly by radio (servo, escapement, solenoid, steering machine, etc.), we have a channel of control.

In the present state of the art, radio equipment which supplies anywhere from 1 to 12 channels is readily available. (Fig. 1-2.) While 1, 2, 3, 4, 5, 6, 8, 10 and 12-channel transmitters and receivers have been, or are now, manufactured, the commonly used numbers of channels are 1, 4, 6, 8, 10 and 12. Of these, the 1, 6 and 10 are most widely employed because of their natural adaptability to commonly desired vehicle controls, at appropriate overall systems cost. (We speak of "reed" equipment when multiple channels are mentioned, ignoring in this example equally popular proportional equipment.)

If we may venture a little farther into the vast electronics field — which really requires a book in itself — it is noted that, when multiple channels are available, the usual practice is to manufacture six or more channels with an ability to employ two channels simultaneously. Simultaneous control is highly desirable in multicontrol stunt airplanes. (Proportional multi automatically is simultaneous, usually on at least three channels — Fig. 1-3.)

Modelers themselves have created a further broad distinction between what they call "single-channel" and "multi." Because of its simplicity, lower cost, and easier operation, single-channel is probably the most popular form of radio control. Within the multi classification, the 10-channel radio is generally preferred for planes, because it requires at least 10 channels (on reeds) to extract full capabilities from an aerobatic airplane. (Two channels each for rudder, elevator, motor, aileron, elevator trim — with steering working off rudder servo and brakes off the elevator trim servo.) For multicontrol boats the trend is to 4 and 6 channels, many people using 6 out of 10 or 12, leaving the others idle.

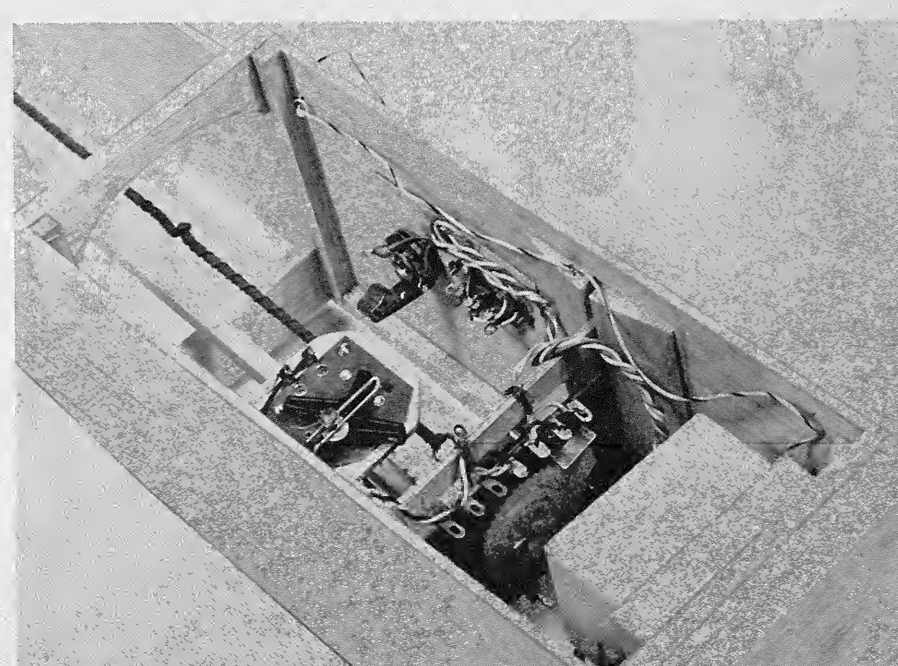
Again, this refers to reed-type equipment. Proportional systems, having from one to four or even five channels (each equivalent to two on reeds) operating simultaneously — with various trim features (each equivalent to two channels) and auxiliary controls —attained wide acceptance in 1963.

To classify radio equipment simply in terms of channels is not enough. We have referred to channels as direct radio links between transmitter and actuator for vehicle control, such as rudder or throttle. The word "mechanical" also has application. For reasons of economy, simplicity or ingenuity, it is common practice (in lieu of true multi) to increase the number of controllable functions with a minimum number of channels — just one, usually — by mechanical or electromechanical means. (Fig. 1-4.)

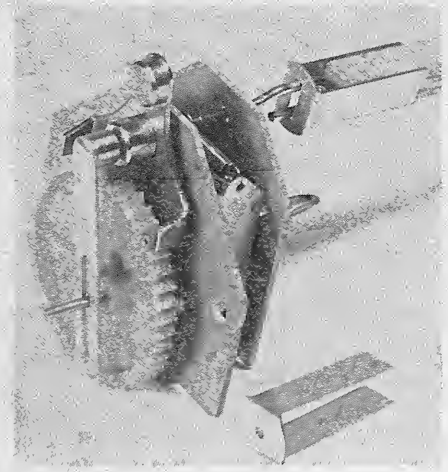
By the use of especially designed actuators (an actuator is the "muscle" which does the physical work of moving a vehicle control), multiple functions become possible on single channel. There is a meaningful relationship here between cost and maximum reliability—ideally, single channel, other things being equal cannot equal multi; two channels are better than one, etc.

Let's talk about actuators. Two types are most popular: the escapement (Fig. 1-5) and the servo (Fig. 1-6). The former is an electromechanical device related in working principle to the common clock or watch escapement, but using a twisted loop of rubber, rather than a spring, for energy. The servo is an electric-motor-driven device. Escapements are employed with simple single-channel systems; servos, as a rule, with multi setups. As a general rule, servos require two-channel operation per servo — one channel for each direction of servo motor rotation. In any receiver, relays, reed banks, or transistors serve as switching devices to close and open circuits to escapements or servos.

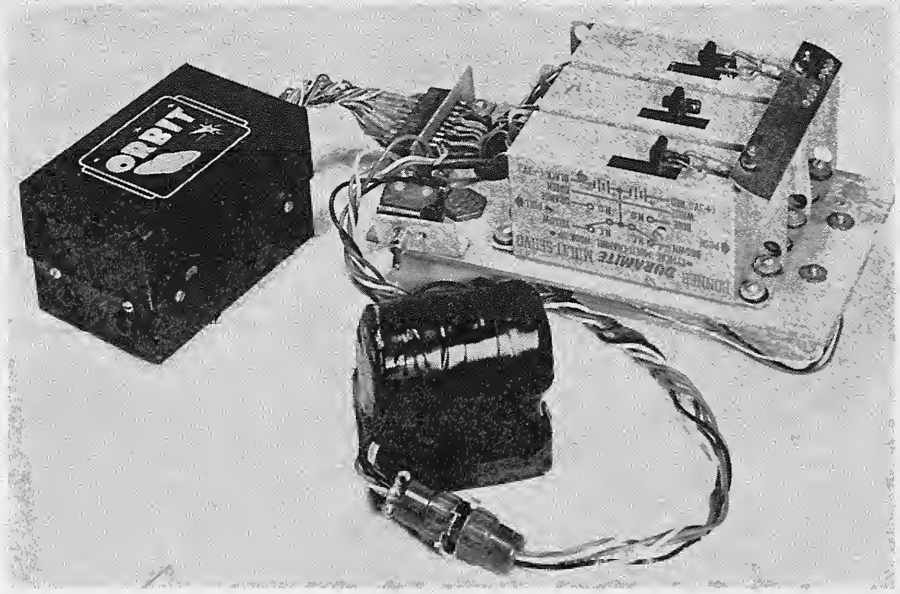
Suppose a servo is supplied for up and down elevator, or right and left rudder. Activation of one radio channel, switching a certain polarity current to the servo motor, drives it in one direction. Relaxation of signal results in an opposite polarity circuit



1-4 **In this single-channel installation the primary escapement — deep in cabin — actuates the rudder; auxiliary escapement, top, triggered by switch on first escapement, works pushrod to engine throttle.**



1-5 **A compound escapement. It works rudder mechanically and contains switching feature to operate a second or auxiliary escapement for another control.**



1-6 **Three servos mounted abreast; motor-control servo is hidden under the mounting board. Near servo is elevator trim; center one, rudder; far one, elevator. Elevator pushrod hooks into the trim bar which joins near and far servos; holes provide adjustment for control movement. Receiver is at left; batteries are in foreground.**

being closed to drive the servo back to neutral. By closing a different transmitter switch, or by moving a lever switch in the opposite direction, the servo can be driven in the opposite direction — from where it again returns to neutral, of its own accord, on relaxation of signal. In proportional systems the servo slaves to movements of the transmitter control stick(s), steering wheel, etc.

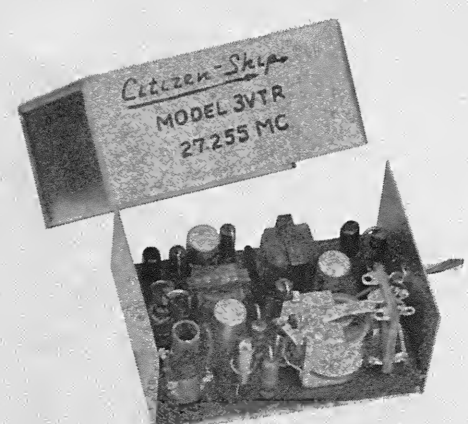
The simplest escapement mechanically supplies both left and right rudder, for an example, on just one channel; and many escapements are so designed that a second and even a third control, in addition to the primary control, may be achieved on one channel. (While some servos fulfill escapement-type operation — one direction of rotation — they are an exception to the rule.)

The natural question arises: If an escapement supplies two, or three, or four controls on one radio channel, why use a servo which requires two channels, or two servos which require four channels? The answer is that escapements generally are confined to low-load functions — and are otherwise limited — whereas the servo is essential for high-load applications, as on large, fast boats and aircraft. Servos allow more precise control, more variations in degree of control. They are less susceptible to vibration. They are less finicky than escapements and do not involve the limitations of rubber-strand power.

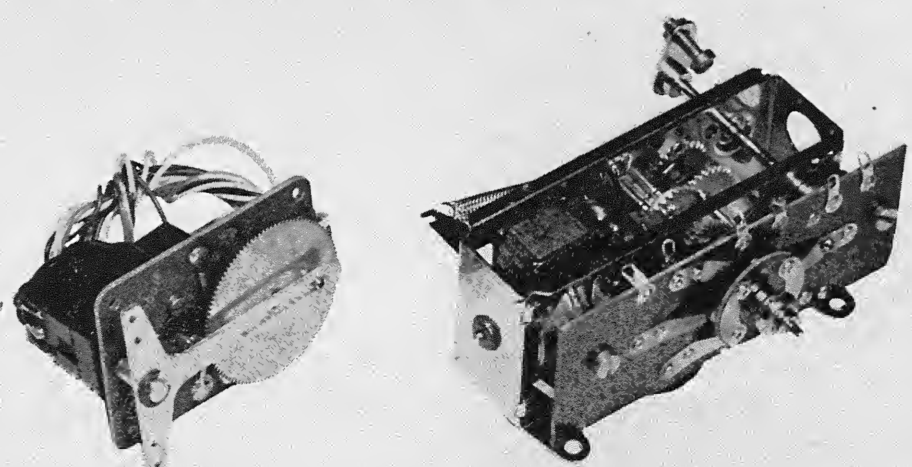
Various "steering machines" exist, the designation deriving from German terminology—since most of these units are of German origin. (Fig. 1-7.) Some small, lightweight, fast-acting servo-type steering machines, when used for small to small-medium-sized airplanes, or very small boats, are just as reliable as escapements and offer special advantages in that no rubber nor special attention is required.

Other, larger steering machines, with a single direction of rotation, are widely used for boats with single-channel radios. These ingenious mechanisms — and they can be quite complex—can be directed by repeated signals, either held on or quickly released, to sequence a wide variety of operations. They perform escapement-type functions, in greater variety, and have more "muscle" for critical applications. And they can be gimmicked beyond an escapement's capabilities.

In a boat, for instance, such a device will yield right and left rudder; high, low, reverse motor; and will blow horns and do other tricky and fascinating chores.



Typical single-channel transistorized receiver of the relay type. Relay closes on signal to close actuator circuit.



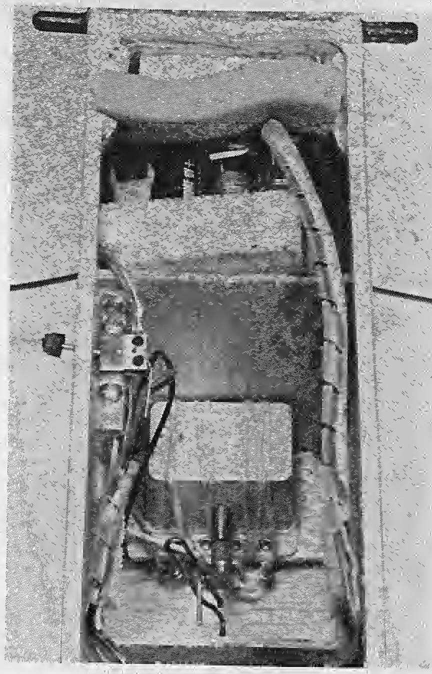
1-7 **Two steering machines. Left: Motorized single-channel servo for airplanes. Right: Boatomatic actuator, for marine use with single-channel control, provides multiple functions to follow transmitter keying.**

You will hear about magnetic actuators. (Fig. 1-8.) Popular in planes only, generally up to .049 power, these actuators slave to an appropriately "pulsed" single-channel signal. In proportional control of other types of vehicles, and of larger aircraft, an electric-motor-driven actuator performs the same function.

Most experts hold that a beginner, notably in aircraft, should start with single-channel. Others state that a multi rig can be used to begin with — but in a temporarily limited manner. The argument in the latter case is that, after you have survived the beginner stage, you then own equipment with greater capabilities, avoiding a double investment. Since the initial investment is a factor in most cases, it is interesting to note that some four-channel outfits do not cost much more than a high-quality single-channel system, and a six-channel is not too costly.

The four-channel receiver, for instance, can be installed in an airplane with an escapement (or escapements) if so desired, or with servos, using from one to four channels. In land and water vehicles it would supply an adequate number of controls, especially when mechanical means are considered for extending the functions within the vehicle on one or more channels. However, the full use of the maximum number of multi channels is not to be encouraged for the beginner (in airplanes) except in fortunate cases where the subject has had other modeling experience, plus the benefit of expert help (in flying) and advice.

In passing we should note two other approaches to radio. One is the building block system in which a receiver is so designed that either a reed bank may be added later for multi, or other modules can be connected to the receiver. There also is the possibility of building transmitters, receivers, and other items from parts kits. This has no bearing on fundamental systems, but influences cost, or permits a step-by-step expansion when circumstances justify it.



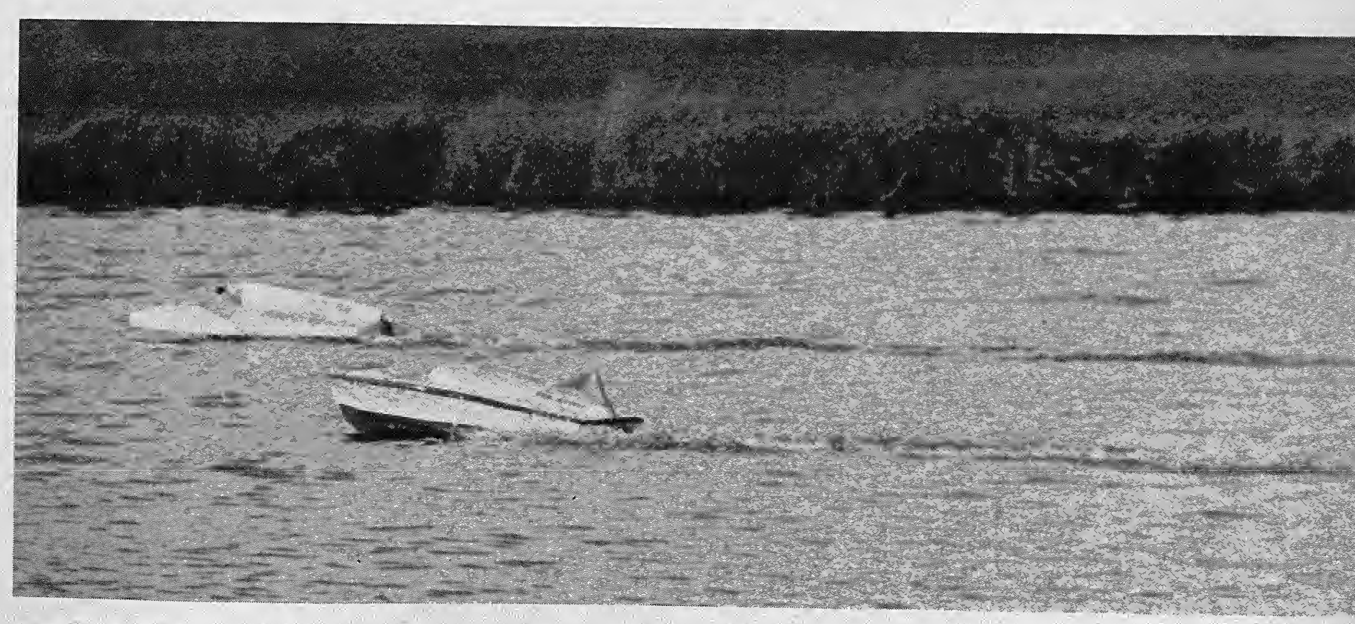
1-8 **Typical magnetic actuator for single-channel proportional control slaves to movements of stick or buttons or knob on pulser unit attached to transmitter.**

What type of model should you build? Obviously, the tyro either has had prior experience with other allied forms of models or he has had no experience whatsoever. In the former case, it is usual to desire a radio-control aircraft or a boat, though the experienced airplane modeler, in 45 per cent of the cases, also has a weakness for marine things. In the case of the previously unexposed beginner, there is less leaning toward one favored type of vehicle, and a boat is a frequent selection. Planes may appeal to this novice, too, especially in cases of father-and-son teamwork. The young fellow, finding aircraft more dynamic, often influences the choice. (Racing hydroplanes are exciting.)

Then there are people with strong electronic experience, either as a vocation or avocation, just as there are mechanically gifted folks to whom machine work is not a deterrent. Some fortunate people combine these skills. So we get into other areas where special vehicles, or scratchbuilt projects, present the required challenge.

Typical are operable derricks and shovels, exotic riverboats and steamers and warships. Trucks and army tanks catch attention. The author has witnessed a battle between two scale army tanks, maneuvering and firing wooden shells; also, a riverboat which exactly duplicated a real-life cruise, even to the figure of the captain coming on deck to welcome passengers while a calliope played. Some hobbyists have even radio-controlled decoy ducks, or built racing hydroplanes, or battleships that fire blanks.

What you decide to build will be governed by various important and natural factors, as well as by personal considerations. Cost has been mentioned several times. Will skill and experience measure up to the demands of a first project in which accuracy of alignment, and strength in a light structure, are required? There are other conditions which decree what sort of a vehicle you can build and operate without problems or annoying limitations.

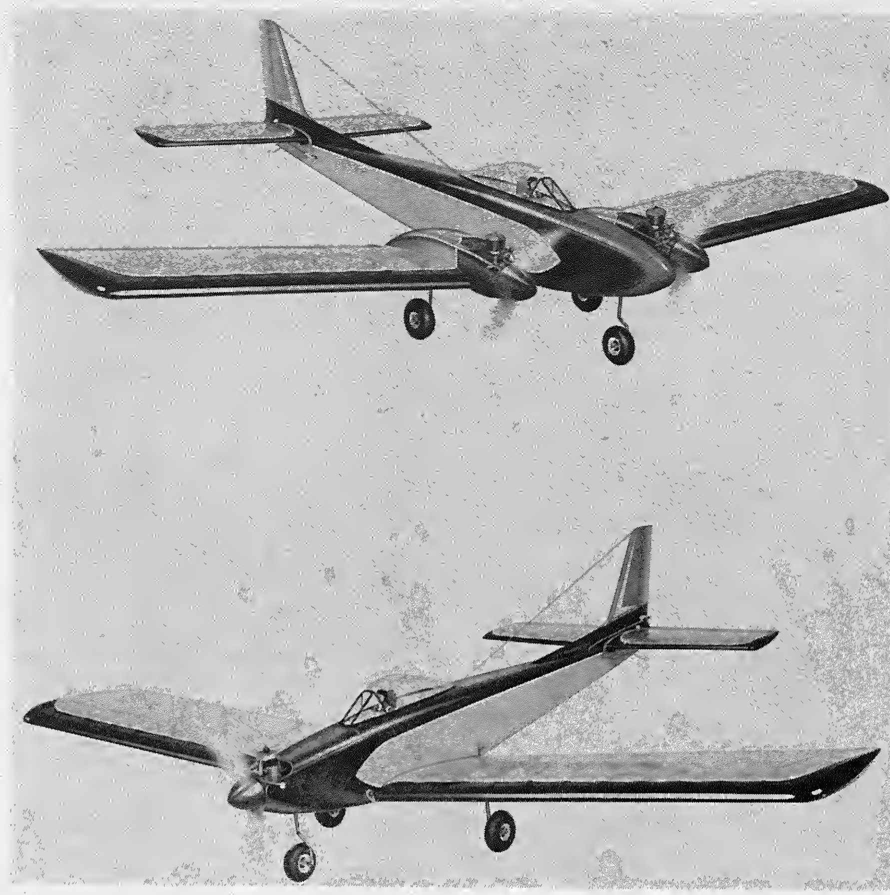


Two fast hydroplanes race simultaneously on a closed course. With multichannel radios they easily exceed 40 miles per hour.

Where do you plan to operate your model? If it is a plane, do you have available a suitable flying field? Most city people don't have a place to fly — nor even many suburbanites, who may drive 25 or more miles to find open spaces. The bigger and noiser the plane, the more difficult the site problem. Homeowners may complain about noise — and you will have to desist.

You need space so that the plane will not strike objects. For that boat — do you have a suitable pond? Very often boat sites abound, whereas plane sites are lacking. But noisy, fast boats (easily damaged) cannot be operated in many parks nor in small ponds. (Mufflers sometimes are available.) Parking lots and paved areas such as schoolyards are wonderful sites for trucks, cars, tanks. And even your backyard. Or living room floor?

How about your working area? What kind of a shop do you have? What about tools and equipment — do they measure up to the contemplated tasks? All these things influence the degree of satisfaction that can be had from building, as well as operating, the project. A large aircraft project is a headache in an apartment where piles of balsa chips and sanding dust fall upon the carpet and dope fumes drive the little woman into issuing painful edicts!



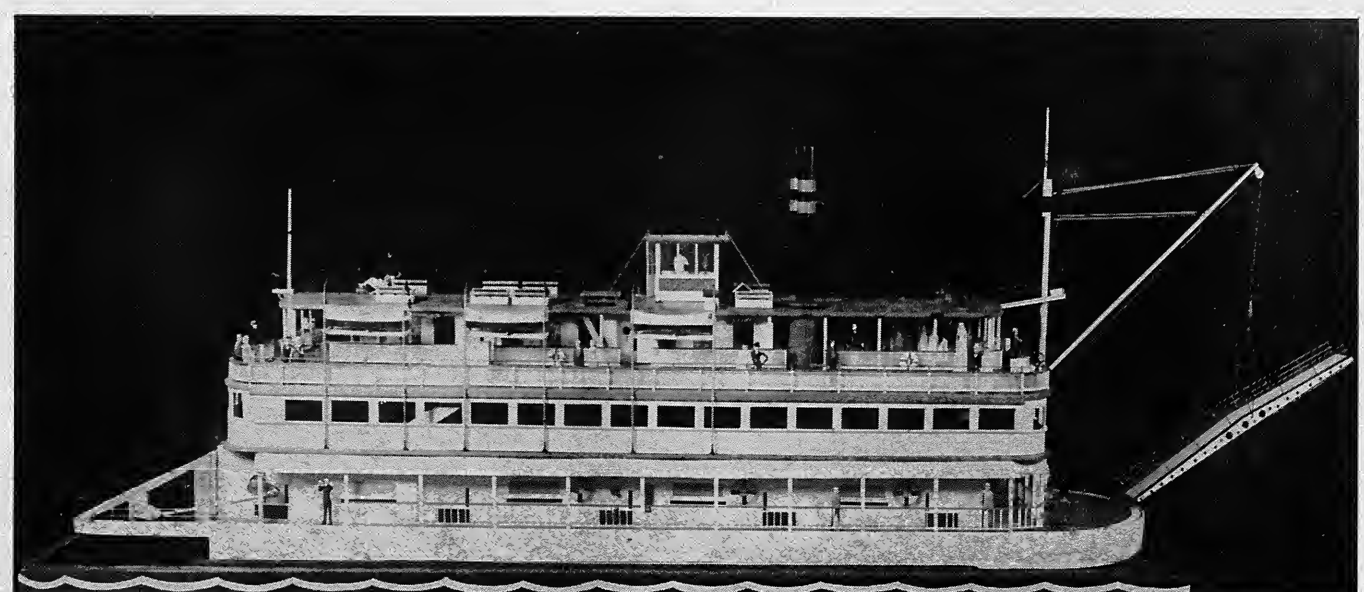
This aircraft for 1 to 10 channels (single-engine or bimotor) is ideal for 6-channel radios — usually with ailerons left off.

If the shop or other working space is limited, the size and type of vehicle is an important choice. A small boat, converted plastic kit, or metal or plastic toy (Fig. 1-9) will allow you to work with all necessary tools and materials at easy reach.

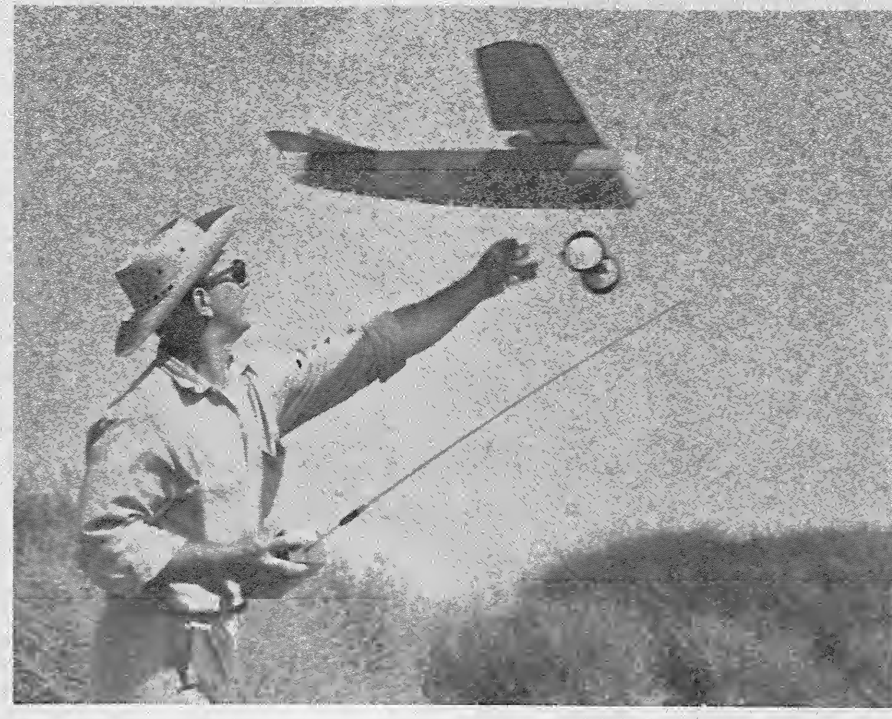
Having allowed for working conditions and space, and equipment, and having considered the suitable site and the most adaptable vehicle for it, how then do you proceed with the choice of the model to build?

Most common source of project supplies — finished craft, construction sets, raw materials — is the hobby shop. Thousands of hobby shops exist, and it is a rare city that doesn't have several. Other retail outlets carry hobby supplies, although, as a rule, advice and help are more readily available from the hobby shop proprietor. Mail order houses are listed in hobby magazines; they have catalogs available. Magazine advertisements display all manner of models and accessories.

The overwhelming majority of hobbyists build from construction sets or kits. These kits come in all sizes and types, to fit all ambitions and pocket-



Excursion steamer has animated figures, operable gangplank, orchestra, whistles. A standard tape recorder is part of its equipment.

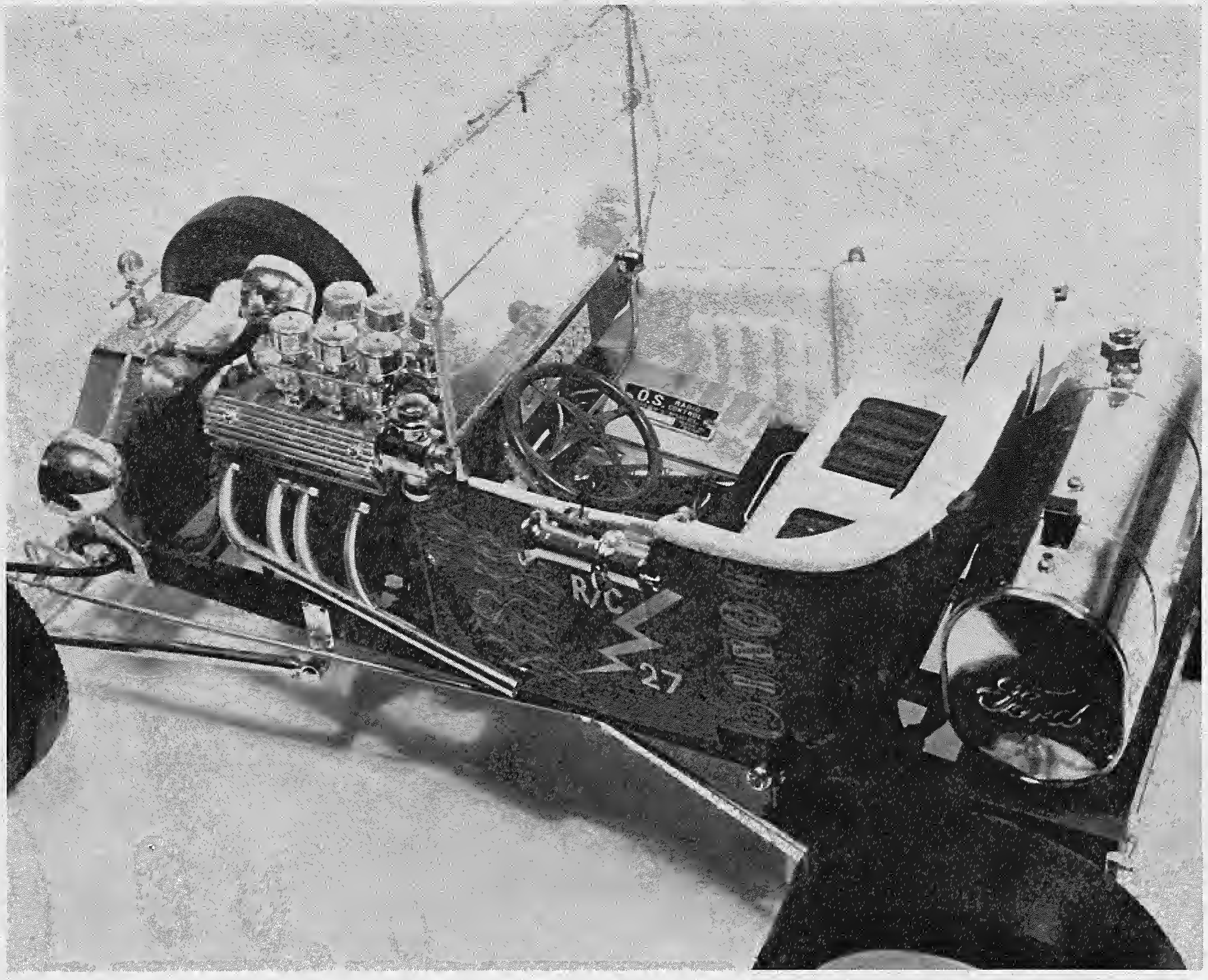


Scale Fokker D-8, used in motorless combat with other scale war craft, is launched from a cliff overhanging the Pacific Ocean, and it rides upsweeping air.

books. They usually require additional materials or accessories which also are conveniently available at the same store. The advantage of the kit is that it contains all basic materials, and the parts are shaped, formed, molded, die-cut or otherwise cut out. Plans and instructions usually are most complete. Above all, it is established that the model involved has been proved during its manufacturing development.

Plane and boat kits abound. Cars, tanks, trucks, not so, although there is a plethora of plastic kits intended for display only (many are dynamic, having an electric drive motor, and are steerable) but which can be converted to radio control if the customer is moderately ingenious and resourceful. This is especially true of the giant-size car kits. Electric motors and gear trains exist in great variety for such conversions. Many toys make excellent projects. Large tanks (and other military vehicles, personnel carriers, guns, etc.) with operable guns and turrets are typical store items not especially difficult to adapt to radio.

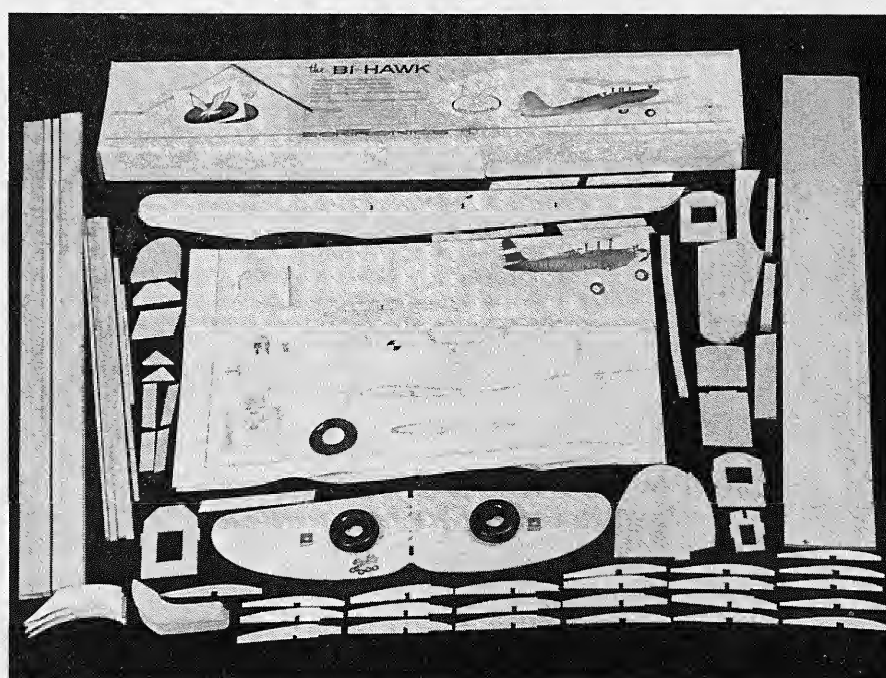
This flying boat beginning its takeoff run has a sealed, watertight cabin. It is about 3 feet in size and has a .049 engine.



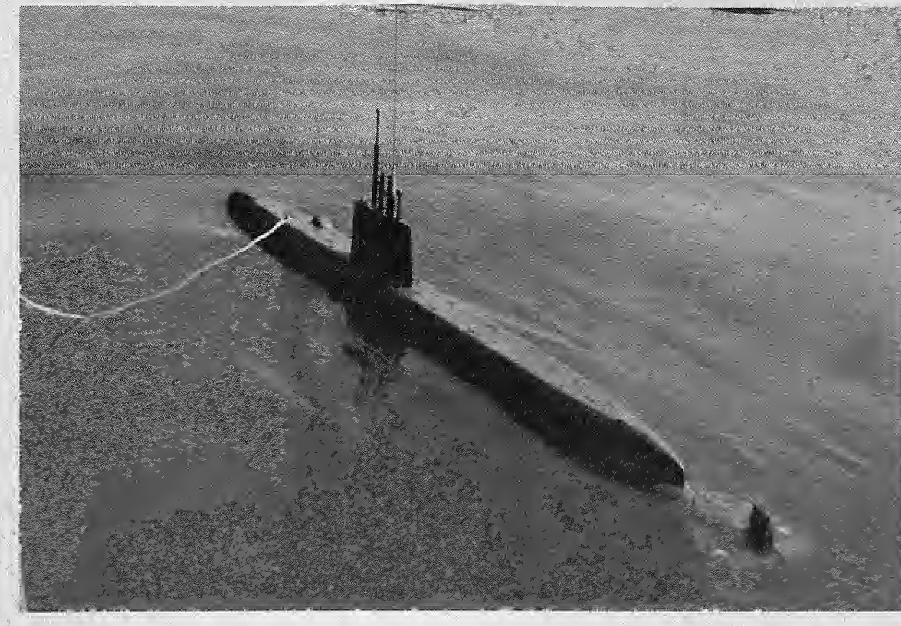
1-9 **This giant-sized plastic car was converted for radio control. Receiver is on floor, right side; batteries are in tank and under seat. Steering machine is bolted beneath body.**

In addition to kits, or converted kits and toys, there is much building of magazine projects, and of scratchbuilt projects from original designs. All hobby magazines publish construction projects and frequently make full-size plans available. Science magazines publish occasional projects — sometimes simple, sometimes most demanding. All these published projects have the dual advantage of being development-proved and of presenting something unusual or appealing. They do require your obtaining all necessary building materials, and for you to measure, cut, shape and sand raw strips and blocks, or perhaps to tap and die or even machine metal parts. The published project is more difficult than building from a kit, but still is simpler than designing your own.

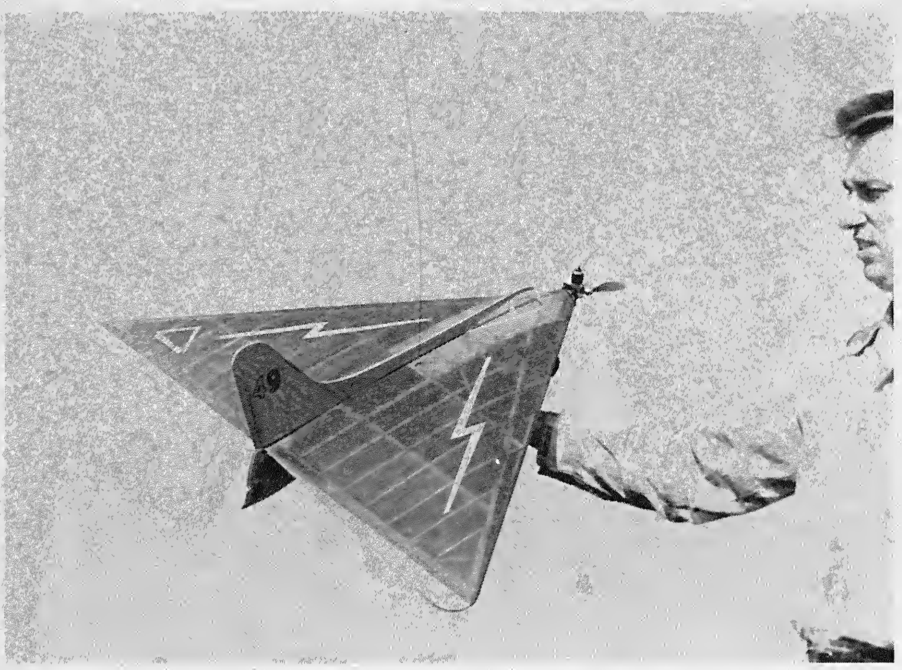
Although many people do create their own designs, it is suggested that you do not try to do so at first, unless you have good understanding of the working principles and proportions of the real-life machine and a well-based



Contents of a typical airplane kit — in this case, a biplane. Wire parts are formed; sheet balsa and plywood parts are die-cut.



Submarines submerge to periscope depth; they are trimmed to submerge on high speed forward. If equipment fails they rise to a waterlogged state of trim.



All manner of original designs are dreamed up by enterprising hobbyists. This delta is extremely stable on single-channel rudder-only control.

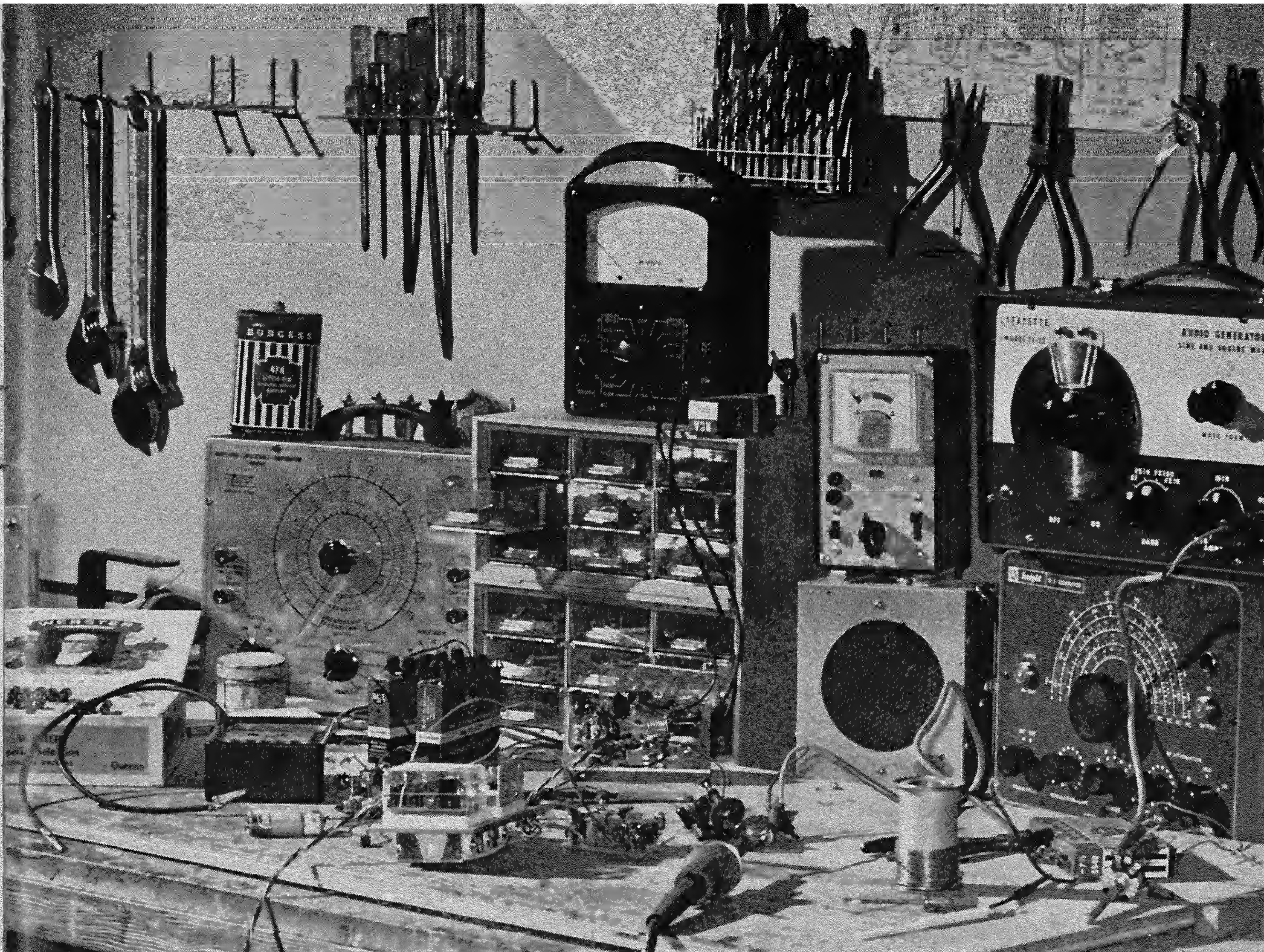
modeling experience as well. This is "gospel" in aircraft and speed boats.

These preliminaries leave us short of solving radio control's greatest problem—installations. For, although most would-be hobbyists are capable people, in most cases they are up against a blank wall when it comes to putting the gear into the vehicle so that it not only works but continues to work reliably. Seldom is the vehicle, as a kit or other form, combined with radio and system components by a single manufacturing entity. Various sets of directions then have to be related. Where one leaves off, the other does not necessarily pick up.

In the following chapters we shall develop guidelines designed to insure successful and enjoyable pursuit of your new hobby. We shall examine, among other things, the basic types of craft and show you how to put your gear into them. We will not discuss radio in detail, leaving this to the manufacturers and the books covering that subject, but will include a section on troubleshooting systems. Not examining methods for isolating a burned-out condenser, or a damaged transistor, etc., this section will enable you to keep a system functioning and to pinpoint the really common causes of failure.

Unless equipment is damaged by careless mistakes in hooking up wires backwards, and so on, it can be considered dependable in almost all cases. If a man knows electronics he can pinpoint electronic component failures with the aid of his test equipment—meters, scopes, etc. If he does not have these, or if he does not know how to use them in testing procedures, he will do best to return faulty equipment to the manufacturer, via his dealer (who may have a repair service), for repairs or adjustments.

The overwhelming majority of malfunctions are field failures — bad contacts, weak batteries, bad connections, inferior soldering, sloppy maintenance and wiring, bad tuning, or sheer forgetfulness, carelessness or neglect.



2-1 **If possible, separate your electronics from your model-building either by using two benches or by apportioning space on one suitable bench. Racks for tools, and convenient electrical outlets (out of picture in foreground, below bench level) promote concentration. Comparatively few hobbyists have as much electronic checking equipment as this.**

2: TOOLS

IN addition to the more common tools — hammers, saws, drills, etc. — many special tools enable the craftsman to accomplish easily the otherwise time-consuming and difficult tasks. A judicious selection of appropriate tools makes for cleaner and neater work.

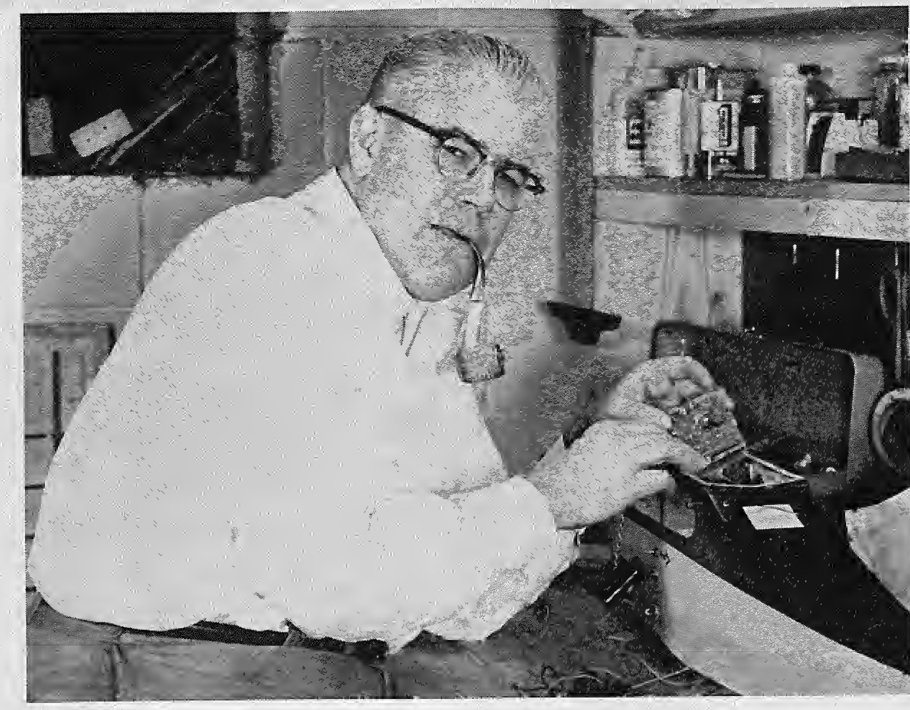
Workbenches and toolboxes: The new hobbyist usually finds any convenient work area or smooth surface to work on, but soon realizes this hasty arrangement has shortcomings that lead to confusion. One should have an "atmosphere" conducive to enthusiasm and orderly work. Here are some helpful tips.

General work area: The location should not be damp nor gloomy. Arrange good lighting facilities. Adequate ventilation is more of a need than is usually imagined. Convenience is essential. If wood is carved or sanded, or if dope is applied, in a living area, the modeler surely will run afoul of the "housekeeper's" objections. Strangely, some hobbyists are not happy unless they can smell cement and dope! It will be found that the less conflict between your hobby and the household, the fewer the problems that arise.

Although circumstances may not permit immediately ideal working quarters and facilities, we can project appointments desirable for sustained activity, and plan accordingly from the beginning.

Consider these things: Good general lighting, such as a long twin-lamp overhead fluorescent fixture. Spot lighting for detailed work — even if only a gooseneck lamp. Convenient electrical outlets for chargers, tools, soldering irons. For chargers, etc., outlets at the back of the bench avoid having cords dangling awkwardly for hours, if not days on end. More accessible, front-of-the-bench outlets will prove better for soldering irons, electric drills, etc., which are used intermittently, since cords will not knock about objects on the bench top. Outlets, especially for power tools, should be grounded back to the panel to eliminate dangers from a short-circuited tool. (Have an electrician install a branch circuit, if you do not know how.)

Plan a separation of space between



The author checks out a receiver installation. Ample space and a good, well-ventilated and well-lighted work area are conducive to best results

model construction and electronics — if you do much radio work this is a must. Bench height should be adaptable to sitting or standing — use a tall stool. An excellent bench can be built from 2 x 3's, 1 x 4's, with a ¾″ thick plywood surface. Use unattached pieces of pine shelving for work boards to avoid damage to the bench surface. Pegboard at the back of the bench for hanging major tools — organize tools as to use, shears, pliers, saws, etc. — adds efficiency.

Obtain a wide-topped toolbox for frequently used small tools. Arrange convenient stands or racks for certain small tools — hand files, knives, drills, etc. Various fixtures for use with pegboard are stocked by hardware stores. These are useful for holding jars, small tools, and such diverse large objects as electric drills and soldering guns.

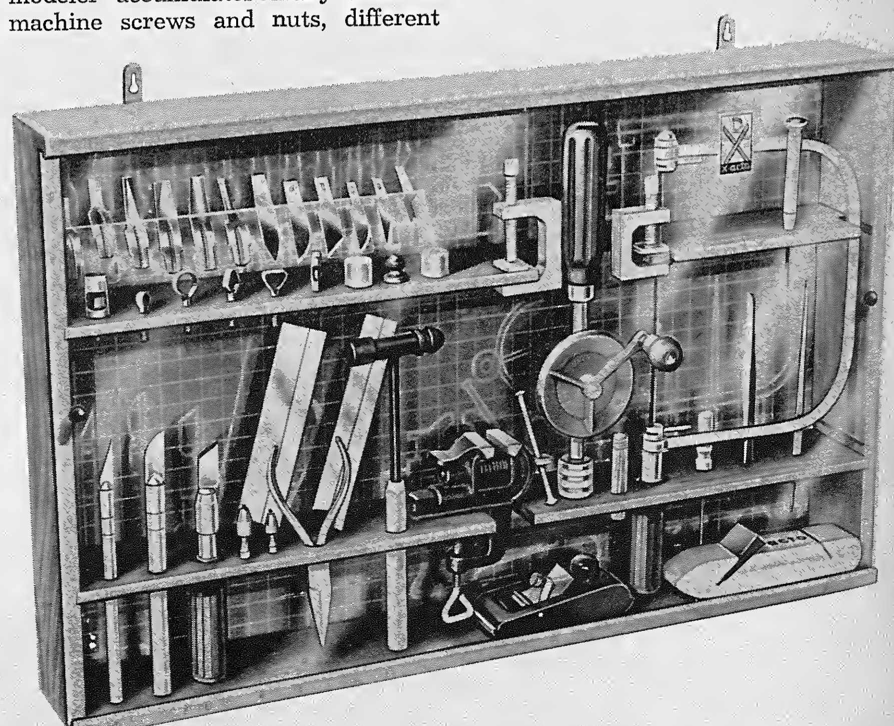
If only one bench, allot one third or one half to electronics, allowing adequate space for working on installations and checking out of complete vehicles. Group all meters and testing devices convenient to that area. Electronic test equipment, such as large meters, scopes, etc., can rest on shelves at the rear of the bench, leaving the surface unrestricted. If your work area is big enough, consider two benches, one for general modeling and a smaller one for all electronic work.

You will need shelves and storage space for materials. Overhead ceiling racks or free wall space will store models. A wood rack should be so designed that wood does not bow nor twist with storage. Pegboard shelf racks or other adjustable wall shelf brackets will handle reference material. Keep all active instructions in a large looseleaf book, available for future reference. Space for kits, large storage cartons, etc., will be found under benches by providing common shelving laid in place but set back from the front of the bench. Fig. 2-1 shows a typical arrangement.

Small parts cabinets: Any active modeler accumulates many sizes of machine screws and nuts, different sizes of washers, needle valves, nylon and plastic fittings, plugs, sockets, switches, and so on. Various inexpensive metal cabinets come in many sizes with clear plastic drawers. If you model actively such a cabinet eventually will prove indispensable. They are handy, too, for storing various radio components, resistors, condensers, etc.

Hammers: The airplane builder most frequently uses a hammer only to drive pins into a work board to hold parts in position for gluing. While any inexpensive small hammer, tack hammer, etc., suffices, he will find convenient such variations as a hammer with one magnetized and slotted head (good for picking up pins), or one with interchangeable screw-on heads for any type of modeling work or any material. X-Acto, for example, makes a most useful general-purpose hammer for miniature work. The fastidious builder will enjoy the feel of a well-balanced tool. Fig. 2-2 shows a useful selection of modelbuilding tools.

Saws: The common coping saw is immensely useful, and many builders get by with a dime-store variety saw. A small carpenter's saw is occasionally useful for cutting large materials and harder woods. Even in plane building, with its comparatively simple requirements in tools, small problems arise which make it desirable to have certain special-purpose saws — although such tools are taken for granted by the all-around craftsman. For example, many a modeler cuts



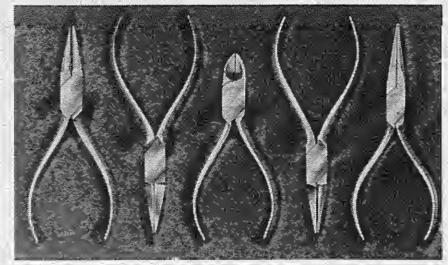
2-2 **The X-Acto cabinet of special modeling tools includes various balsa knife handles (left) with many interchangeable knife and saw blades.**

brass and aluminum tubing by rolling it back and forth beneath a sharp edge of a Stanley knife or even a single-edged razor (either of which is ruined in the process). This job is best done with a razor saw (Fig. 2-3), to be found in most hobby and craft stores. This saw has a rigid blade with small teeth ideal for this purpose. It is particularly handy for diagonal cuts of metal tubing pieces which are to be soldered together, for cutting metal hinges, and the like. A common hacksaw, of course, is proper for heavier metals.

Another handy saw involves an X-Acto-type knife handle and a miniature keyhole-saw blade which attaches to the handle and is replaceable. The blades can be bought separately. Such a saw finds innumerable uses in any model shop, handling tasks not possible for larger saws.

Any serious hobbyist becomes aware of a handicap in not having a jig saw or band-saw power tool. As a compromise, there are inexpensive vibrator-type jig saws which are superior in speed and accuracy to a hand jig saw. Balsa blocks are quickly cut to shape with such saws, as are plywood formers, bulkheads and other parts of Micarta and even thin, soft metal.

Pliers: Diagonal (dikes) cutting pliers, electrician's pliers, needlenose, duckbill and round-nosed types all play an active part in almost any modeling project. For practical usage, you really need two and even three sizes of pliers in some categories. Using small pliers to cut or bend heavy or hard materials will nick or deform the tool. In really small sizes convenient for electronic work, the commonly used pliers can be found in complete sets. Medium-sized and large slip-joint pliers are versatile aids, especially for holding work while wielding some other tool. Gripping and holding things is a constant factor in modeling, so that many related tools and devices can improve efficiency and neatness. Adjustable, lock-set pliers have viselike qualities. (Fig. 2-4.)



A set of small high-quality steel pliers is a worthwhile adjunct for such work as assembling receiver or transmitter parts.

Vise: A medium-sized vise, substantial enough for bending light sheet metal parts or heavy steel wire up to $\frac{5}{32}''$ diameter, is essential. If the vise is of the type that pivots on its base, locking in convenient positions, so much the better. Not essential, but desirable, is an additional small vise for more delicate work—such as holding sockets and chassis for wiring.

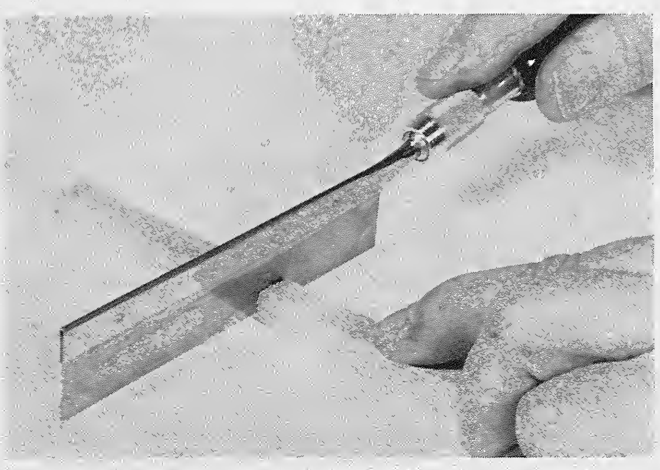
A selection of C clamps and other spring-loaded clamps of various sizes is recommended. Miniature clamps intended for hobby usage are sold at model shops. The hardware store may have broad-billed, spring-loaded clamps — intended for holding wood to be glued — which are ideal for heavier model work. Stationery stores have various spring-loaded paper clamps, handy for gripping sheeted leading and trailing edges for gluing, and so on. Ordinary spring-loaded clothespins are adaptable to many little jobs and frequently avoid the need for straight pins to position wood parts. Large, adjustable wood clamps also are a hobby shop item.

Sharp-edged cutting tools: Since modeling involves much cutting of wood of various sizes and textures in infinite ways, all sorts of cutting tools are pressed into service, beginning with that old favorite, the single-edged razor blade. For industrial use, such blades can be bought cheaply in quantity at paint and hardware stores. Less expensive drugstore brands, etc., are good for wood cutting.

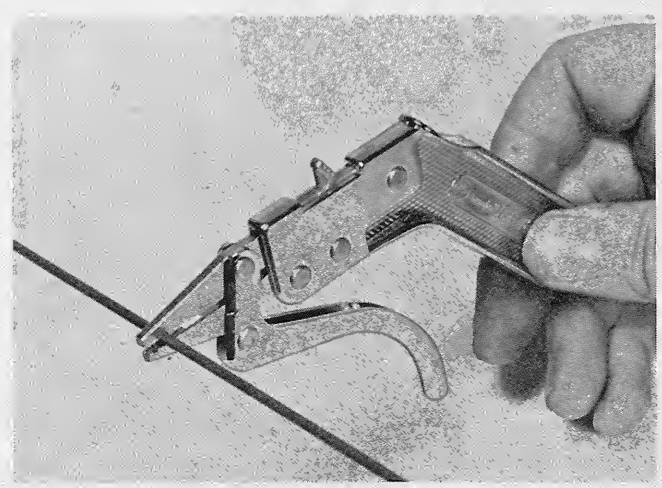
For delicate, precise work, X-Acto makes an impressive line of hobby knives, widely used in many crafts as well, which have surgical steel blades in a variety of shapes conducive to handling any tricky cut. The blades quickly insert into, and lock on, a special handle. Replacement blades come in inexpensive packages.

For heavier work the Stanley knife is excellent. With a larger handle and bigger blade, these knives are hardware store items, used for cutting many household materials. The blades are quite sharp and will handle balsa without crushing the fibers. The sharpness can be restored fairly well with a fine stone, but replacement blades are inexpensive. The Stanley knife is particularly useful for making long cuts in thick balsa, or in thin pieces of harder material; for stripping, etc. For long cuts, a metal edge can be C-clamped in place over the material, making an accurate guide.

Various chisels and gouges are a good investment that will add versatility to your efforts. For hobby work, Millers Falls makes a matched set of five gouges designed to handle among them just about any appropriate problem you will encounter. They are excellent for hollowing out small hulls, wing tip blocks, and nose blocks, and for making all kinds of slots and grooves, or simply cutting wood in some inaccessible spot. These tools are easily sharpened according to directions with the set, on the small stone provided for the purpose. (Fig. 2-6.)

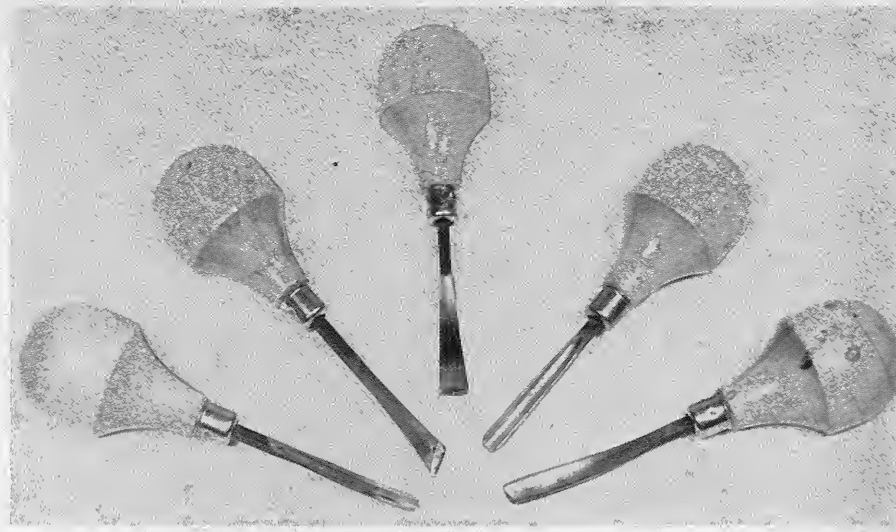


2-3 **X-Acto fine-tooth razor saw — in knife handle — is typical of cutting methods for harder materials or for balsa strips $\frac{3}{8}''$ square and larger.**



2-4 **These pliers will clamp work in position to facilitate holding or to use a second pair of pliers in the other hand.**

2-5 **The adjustable balsa stripper is a versatile tool for cutting special strip sizes from sheet balsa. An ordinary balsa knife fits into the holder.**



2-6 **Millers Falls gouges come in sets of five for hobby use. Such gouges are valuable assets when working with balsa blocks.**

2-7 **Small wood planes are useful for dressing wood strips and are particularly desirable for shaping leading edges.**

2-8 **Pin vise finds many uses in model-building, notably for drilling small holes in places otherwise inaccessible even to small hand drills.**

Balsa strippers: The need for non-standard-size strips can be met with a stripping tool which slices strips of the desired thickness from appropriate sizes of sheet balsa. A most convenient tool is the X-Acto balsa stripper (Fig. 2-5). A setscrew on the top of the tool allows adjusting of a guide on the flat bottom of the tool which rides along the edge of the sheet balsa. A balsa knife is fitted into the tool and is held in place with the hand, pressing the cutting edge into the wood as the tool is drawn along the length of the wood. (Fig. 2-5.)

Wood planes: It will be found that a small keen-edged plane is superior to a knife in many instances — as for rounding off a wing leading edge, or shaping a solid wood nosepiece, etc. The wood plane will make long, even cuts, making it easier to shape wood accurately and quickly. Hardware stores have reasonable small planes, but special modeling planes are available at the hobby shop. (Fig. 2-7.)

Files, rasps, etc.: Metal files find constant use in all phases of modeling. While medium-sized files of the hardware store variety are more or less standby items for odd-job applications, small files of various shapes and cross sections are highly desirable for our purposes. Miniature files, like miniature gouges, can be purchased in sets.

Since we work so much with wood as well as with metal, wood files and rasps are well worth having. A round wood file, for example, is a most advantageous tool for rounding out window corners and enlarging holes. Larger rasps are handy for preliminary shaping of blocks, etc.

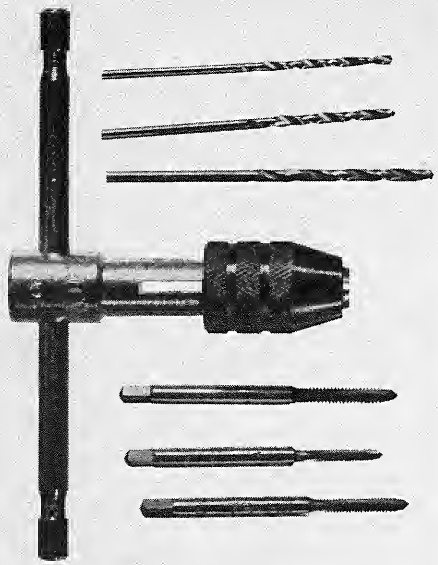
If any advice can be given on file selection, it is to buy quality tools. A sharp file always cuts more quickly, and good-quality steel means that the tool lasts much longer. A wire file brush is desirable for cleaning the teeth of metalworking tools.

Drills: A medium-sized hand drill is indispensable. In fact, it is wise to have an additional small hand drill for light work with thin bits. A power drill will save so much work that it will, in time, repay the investment. No hobbyist will ever regret purchasing both wood and high-speed metal-cutting bits, especially if obtained with drill gauge and rack. Keeping drill bits loose will prove unsatisfactory in many ways and will be a constant irritation. Incidentally, many hobby shops having railroad departments stock very small gauges of bits for use with an appropriate small hand drill.

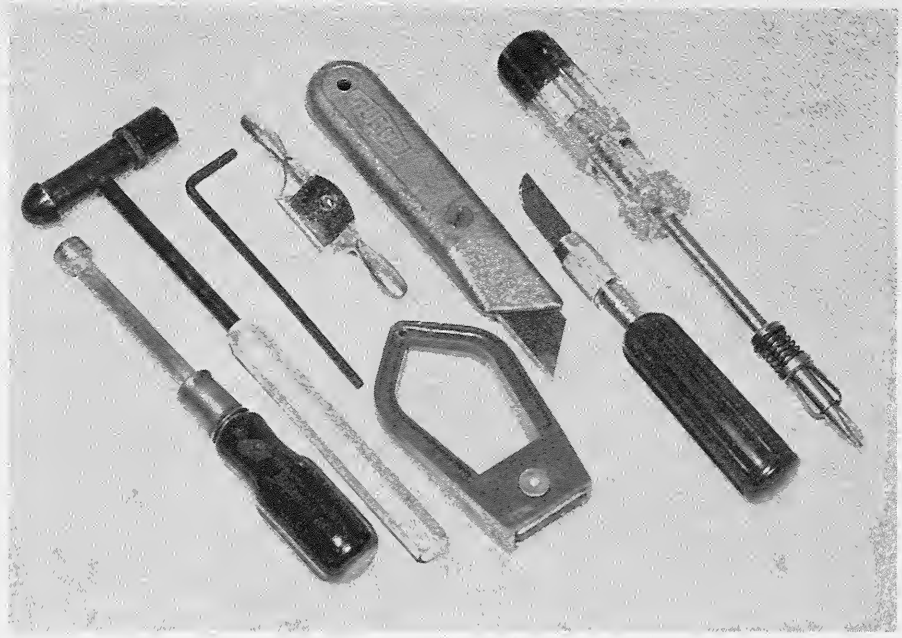
Pin vise: Related to both a vise and a drill, this handy tool (also called hand drill) has surprising applications, although most modelers seem not to have heard about it. Described simply, it has a multi-flat-sided handle with a small chuck in both ends, capable of grasping the tiniest drills or a straight pin from which the head has been removed. The pin vise will get into hard-to-reach spots, and is most convenient for working on small pieces held in the hand. (Fig. 2-8.)

Other convenient tools: The sharp-pointed awl is good for starting holes in wood that is to be drilled, and has other uses as well. A small center punch is useful on metal, for indexing holes to be drilled so that the bit will not move out of position. Glue guns, plastic or metal, can reach into otherwise inaccessible locations — and speed up work because the glue is always ready to flow by merely pushing a plunger, or by squeezing the plastic bottle dispenser.

Machinist's tweezers (hardware



2-9 Tap and die sets for threading holes in metal to accept commonly used machine screws (2-56, 3-48, 4-40, etc.) are worthwhile for an active hobbyist.



Useful small tools include: spin-tight wrench, X-Acto hammer with interchangeable heads, various Allen wrenches (the L-shaped tool), miniature spoke-shave, small magnet for picking up steel straight pins, Stanley knife with replaceable blades, balsa knife with replaceable and interchangeable blades, screwdriver with fingers for grasping screws (various head types) to start them in hard-to-reach places.

store) are excellent for inserting small objects into obscure locations, removing dropped parts from compartment corners, or even positioning light work. The reamer, in several sizes, often proves useful. Two sizes will cover normal requirements — for enlarging round holes in metal or plywood; for mounting holes for sockets, switches, etc. Tap and die sets (Fig. 2-9) are important to anyone who works much with metal. For example, by tapping a thread into holes in sheet metal, various objects—engines, for example — can be bolted in place without resort to nut plates or blind nuts.

Screwdrivers: Like the hammer, the screwdriver is a prosaic tool, but again there are timesaving innovations for the hobbyist. It will be found that many Phillips-head or Allen-head screws and machine screws will be encountered in accessories, notably in engines. Therefore, it is desirable to have a set of both Phillips-head screwdrivers and Allen wrenches in all commonly used sizes. In screwdrivers experience shows that it is necessary to have suitable variations in the smallest sizes, some with rather long shanks for reaching into "deep" places or confined spots. A few special screwdrivers with nut-holding fingers for grasping a screw when both hands will not fit through an opening occasionally will be found the only practical means of handling some unexpected problems.

Spin-tight wrenches: Consisting of a screwdriver-type handle and a long shank with a socket end to fit the nut, these tools (also called nut wrenches), in many sizes for standard nuts, are extremely useful in rapidly removing or tightening nuts, especially in difficult locations. Typical applications: engine mounting bolts, servo mounting bolts. When much trial fitting is required, the spin-tight is most efficient. Several to a half dozen spin-tights for nut sizes commonly encountered in modeling are a worthwhile complement to your tool set. This tool is particularly handy when holding an awkwardly positioned nut while a bolt or machine screw is rotated with a screwdriver in the other hand.

Soldering irons: Almost any soldering job can be performed with an Ungar or Sidco cord iron which comes with various sizes and shapes of tips that screw into the handle or holder (like a flashlight bulb). The tips are rated in ohms for various degrees of heat. For example, a large chisel tip of about 37 ohms resistance will han-

2-10 Typical soldering irons include Weller soldering gun (right) and Ungar (with interchangeable pencil tips). Wire tool (center) cuts and strips wire without damage to strands. It is adjustable for different gauges.

dle the heaviest steel wire (5/32") commonly used in modeling, without making a "cold" joint. Various tips of from, say, 18 to 28 ohms resistance are good for ordinary wiring of receivers, cables, etc.

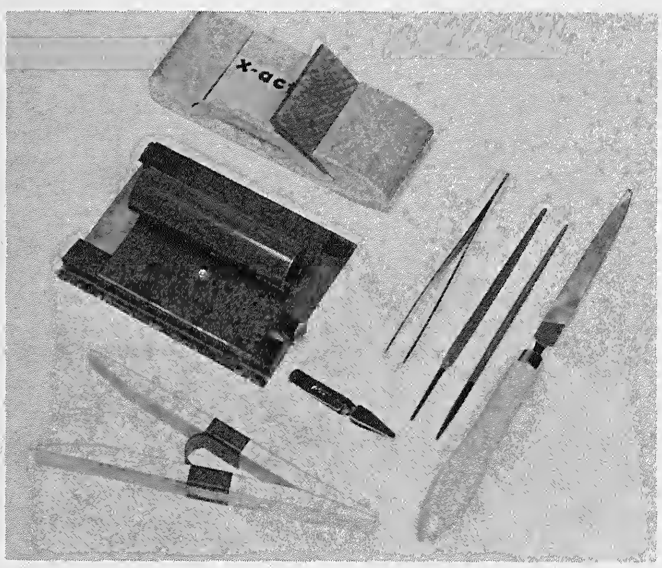
Soldering guns (Weller, for example), for all but the finest wiring, are desirable when many joints have to be made, one advantage being that the iron is not always turned on nor inclined to overheat. These guns are equipped with a trigger and heat up almost instantly when the trigger is closed. Replacement tips can be bought cheaply. Two small lights on the iron illuminate the immediate work area. (Fig. 2-10.)

Wire tools: Several types are available. The better ones permit setting the tool to the exact numbered gauge of the wire. However, cheaper ones (usually about $1 in a hardware or electronics store) are suitable if carefully used. They can be set to any wire size by adjusting a screw. However, after such setting the tool should be tried on a wire sample and the strands inspected for nicks after skinning. It is imperative that wire strands not be nicked when insulation is skinned away. These tools usually can be employed to cut wire as well as to strip away insulation. For our purposes there is no other reliable method of skinning wire, so the wire-skinning tool is a must item.

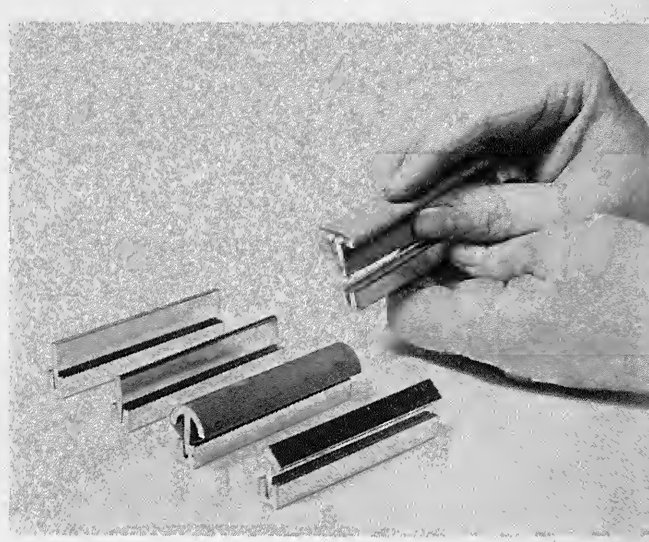
Sanding tool: Handy sanding tools frequently are superior to homemade sanding boards and blocks, although these, too, always have a place. Cheap sanding tools can be had in paint and hardware stores. Smaller ones are found in hobby shops. The former clamp a piece of sandpaper over the flat metal sanding face when a metal lever is tightened. The hobby shop sander is a simple wood block, and the strip of paper wraps lengthwise around the tool, being clamped tightly in place by inserting the hardwood wedge into a special slot.

Vibrator sanders: These have a flat sanding surface similar to that of the cheaper tool, but larger; and a vibrating device within the tool causes a very slight oscillating action of the sanding surface. When held against the material to be smoothed, the tool is quite effective and accurate. Many tools, incidentally, are stocked by trading stamp redemption centers.

Pins: Pins play such an important part in modelbuilding — essential in balsa construction — that they can be considered a tool. About all the average modeler knows about pins is that they come in a more or less standard size on a paper for 10 or 15 cents. Actually, pins may be brass or steel, and the former variety is not very useful to us. Steel is stronger, and bends less readily when tapped with a hammer. Steel pins can be picked up with a small magnet, which is a great convenience for salvaging pins for reuse or when cleaning the bench. Model shops frequently stock very small pins, desirable for dainty work. Larger pins are good for holding heavy strips in place, as when assembling a wing, on the bench top or work board. T-shaped banker's pins and other paper pins with large heads will avoid a sore finger when a great many pins have to be pushed into the work.



Typical sanding tools (top and left). With them are shown two modeling spring clamps, tweezers, and three files which fit the handle on the flat file at right.



For sanding special shapes, these two-piece sanding tools by X-Acto eliminate wrapping pieces of sandpaper around dowels or blocks. Wrapped over the working head, the sandpaper wedges into the base when the metal sections are pressed together.

3-1 **Representative samples of adhesives and dopes. In cans, bottles, squeeze bottles, spray cans and tubes, there are products for every stage of construction and finishing, and for all materials commonly employed.**

3: MATERIALS

BECAUSE we hobbyists so often think in terms of model airplane cement and balsa wood, we sometimes fail to take advantage of the many special-purpose cements, glues and paints which are superior for particular jobs. (Fig. 3-1.) Many such materials have come into widespread use in recent years — contact cements, epoxies, white glues, etc. Although aware of these glues and cements we often are reluctant to "try anything new." If we do try them, all too often the trial is inadequate, or the substance is misused and foolishly condemned.

Water-soluble white glue, for instance, should not be used in the bilge of a boat but is sometimes useful in aircraft — in addition to many special model airplane cements, of course — when normal covering and doping automatically protect it from moisture. Dissimilar materials which cannot be glued together satisfactorily with white glue or model airplane cements can be joined effectively with an epoxy-type cement. And so it goes.

Model airplane cements: Years ago modelers dissolved celluloid in acetone to make "glue." Today's fine cements are formulated in as many ways as there are grades of gasoline. Cements have various characteristics which determine their use: they can be regular, fast, or even extra fast, drying. Depending on their makeup they can interact with various brands and types of paints and colored dopes when improperly used. Compared with most other adhesives they all are fast drying, but the serious builder does not ordinarily use a cement that is labeled extra fast drying — which he regards better for quick field repairs — whereas the impatient young fellow prefers a fast drying agent.

Some cements are "fuel-proof" or fuel-resistant, which means they should not soften because of spilled glow fuel (which contains methanol) or from exhaust deposits. A fuel-proof cement is best used around motor mounts and similar critical areas—the engine compartment of a gas-engined boat, for example. (An epoxy is best in this instance, however.)

You frequently will hear the term "hot-fuel-proof." Here, the modeler is referring to the ability of a glue or finish to withstand deterioration from contact with exhaust gases and other burned deposits. However, not all so-called fuel-proof substances are impervious to prolonged exposure to raw glow fuel (alcohol fuels) which may be spilled onto the model while filling a tank, etc. When fuel is spilled, it is advisable to wipe it off immediately with a rag.

Butyrate-type cements and dopes are fuel-resistant. Nitrate dope is impervious to gasoline-oil mixtures — as used for the Ohlsson & Rice Compact boat engine. Nitrate dope can be protected from glow fuel by giving it a thorough coat of a high-quality fuel-proofer — special clear liquid for this

3-2 **The author's Lightning Bug rudder-only airplane for tiny Cox .01 displacement motor and relayless receiver: all-balsa construction except for Silkspan-paper-covered wing. Decorative decals are available in numbers, letters, emblems, in many sizes.**

specific purpose only. However, butyrate dope is recommended when glow fuel is used.

Cement comes in various sizes of tubes, bottles, cans and plastic bottles, some containers serving as dispensers. If the purchase of a pint or quart of cement is warranted, an appropriate thinner (similar base) should be obtained — air causes a gradual thickening as the cement stands in the container. Various plastic and metal glue guns and squeeze bottles expedite more complex projects where there are many, or hard-to-reach, joints.

All critical joints should be double glued when using model airplane cements — that is, the surfaces to be joined are coated with cement, are allowed to dry or almost to dry, then are recemented and brought together under whatever pressure is required. Thin cement especially will soak into the material, resulting in a very poor joint if only one coat is used.

White glue: Intended for household use, furniture repair, etc. This water-soluble glue is extensively used but it takes longer than model airplane cement to set. It dries rock-hard and colorless. Although sometimes used throughout for larger models, such as multicontrol aircraft, it is best utilized for highly stressed joints, hardwood, plywood, installing motor mounts, etc. When used for laminating thin balsa sheets, the moisture in the glue causes the wood to bend along the grain, requiring many pins, clamps or weights to hold the laminations evenly in place. Dried glue that appears along the edges of laminations is bothersome to sand. Although water-soluble, white glue is safe in planes.

White glues come in various sizes of plastic squeeze bottles. They are economical in larger sizes.

Contact cements: Excellent when properly used, these cements can save weight and much building time. Contact cements are especially convenient for assembling large laminations, fuselage doublers, large blocks, or sheeting to wide structural members. The cement is brushed, or spread, on the two surfaces to be joined and is allowed to dry, after which the surfaces are joined under pressure—vise, clamps, weights (old batteries), etc. Or, if placed upon a smooth, firm surface, position a piece of plywood or board over the work and press upon it with the hands. Once pressure is applied, the bond between laminations is satisfactorily achieved. Contact cement is not suitable for highly stressed joints, nor for general modeling.

Another common use for contact cement is the bonding of a receiver to foam rubber which in turn is bonded to a plywood slide. In such cases any exposed circuitry under the receiver chassis — circuitry which comes into direct contact with the cement — should first be protected with two coats of model airplane cement. If used over exposed circuitry the contact cement can cause shorts.

Epoxy cements: Although there are variations in these cements it will suffice to discuss the epoxy resin found in hobby shops: that manufactured by Klenks is typical. Colored (and clear) epoxy paints also are available at your dealer's under the Hobbypoxy label, by Pettit. Epoxy resin can be used as a finish (when so designated by the manufacturer) in certain instances, but most commonly is the adhesive agent used with glass cloth when fiberglassing. The resin is mixed with a catalyst — such as 10 to 12 drops of catalyst per ounce — in a quantity that can be used within, say, 30 minutes. The catalyst controls the setting time — temperature also has an effect upon the drying cycle. As a finish, the surface is first smoothed as required, is coated with the activated resin, and the bubbles are worked out; then it is given a second coat which is allowed to dry. After a light sanding, the final coat is brushed on. A heat lamp will hasten the process. Hobb-E-Craft packages this product in containers of various sizes.

Epoxy cement has enormous gripping power on many kinds of materials. The joined parts virtually are "welded" into a single unit. Epoxy cement is good for motor mounts, especially in a boat hull for a big gas engine, and for similar purposes. Another typical usage: The brass tube extending through a hull bottom to take a drive shaft can be firmly mounted with a molding of plastic balsa well covered with epoxy. Epoxy is more reliably fuel-proof than even butyrate dope, and will withstand direct soaking with fuel. Resin finish makes a tough finish impervious to the exposure to exhaust so heavy with these big-engined craft. Boat interiors can be similarly coated in the vicinity of gas engines.

Glass cloth: Available at many outlets, glass cloth is especially packaged in appropriate weights for hobby shop use. It is applied, with the resin, to strengthen critical surface areas (such as for abrasion of airplane noses on concrete runways), and, in laminations, inside or over molds to create shell fuselages, hulls, cowlings, etc. (See fiber glass, following.)

Covering materials: Japanese silk, Silkspan, silk, nylon and, to a limited extent, fiber glass, are used for covering. In fact, even Saran wrap and aluminum foil have been successfully used.

Jap tissue is good only for very small R/C airplanes using .01 to .02 sized engines, but for larger planes it can be applied in two layers with the paper grain at right angles. Tissue is applied dry, with the edges dope-adhered to the perimeters of the airframe. It is then water sprayed; upon drying, it pulls drum-tight, and then

is doped — usually three to four coats of clear dope.

Silkspan is much tougher and somewhat heavier than tissue. It comes in heavy and light weights, sometimes designated as gas-model and rubber-model grades. Its texture is like that of a tea bag. It does not tear readily when wet, so it can be applied to the frame either dry or wet. For wet covering, fold the material — as few folds as possible — and dip it into a shallow pan of water. Remove, sop up the excess water on a padded towel, and lay the paper over the frame, unfolding and extending it as you do so, finally pulling out any wrinkles. Once familiar with wet covering techniques — more difficult for the beginner — you can get better covering jobs with fewer wrinkles. Silkspan is perfectly acceptable for small R/C planes. (Fig. 3-2.)

Silk comes in various weights and colors and, unfortunately, in many variations in quality which are not easily detectable without experience. Very light silk can be used on any airplane from about 24″ wing span up to, say, 54″. It will puncture fairly easily — from weeds, twigs, etc. — but is superior to Silkspan. A heavy weight is better for larger craft. Silk also is used to seal and strengthen balsa surfaces, as on an airplane fuselage, boat hull, etc.

Silk should be examined for weave — note that the material has a "grain." (It tears more easily in one direction, with the grain, than the other.) Some silk is close-weaved, requiring less dope, while other silk is open-weaved, not only requiring more dope to fill the "pores" but tending to pull apart when stretched over framework. Some silk has been "sized" or chemically treated for other use, modeling being a by-product. Such silk, quite common, feels stiff and is more difficult to work with than better-grade material. The wrinkles or fold lines are hard to work out. The sizing will rub off when the wet or doped silk is rubbed with the fingers to smooth out over wood surfaces, and is a bit of a nuisance.

Silk is applied wet or dry, grain lengthwise to all covered areas: tip to tip, nose to tail, bow to stern, etc. One advantage of silk — other than that of superior strength — is that it can be stretched in any direction around compound curves without causing wrinkles, and it does this most easily when wet with water. If wrinkles appear after preliminary stretching of the silk — that is, before the entire surface is doped — the offending doped edges can be loosened with dope and can then be pulled tighter to remove the wrinkles. (This is also true of nylon.)

Surfaces to be covered should always be given a prior coat of dope if the wet covering method is used. Of course, the use of sanding sealers, etc., accomplishes the same purpose. Wide structural members (trailing edges, for example) should be dope-protected against water before wet-covering. Silk, dipped in water, should be placed upon a soft towel to remove excess water before the material is stretched upon the frame.

To trim silk (or nylon) neatly, allow the dope used for application to extend beyond the frame edge for ¼″ or more. When dry, the doped silk cuts easily with a single-edge razor blade. If the overhanging material is left undoped, a rough edge results from snagging when trimming.

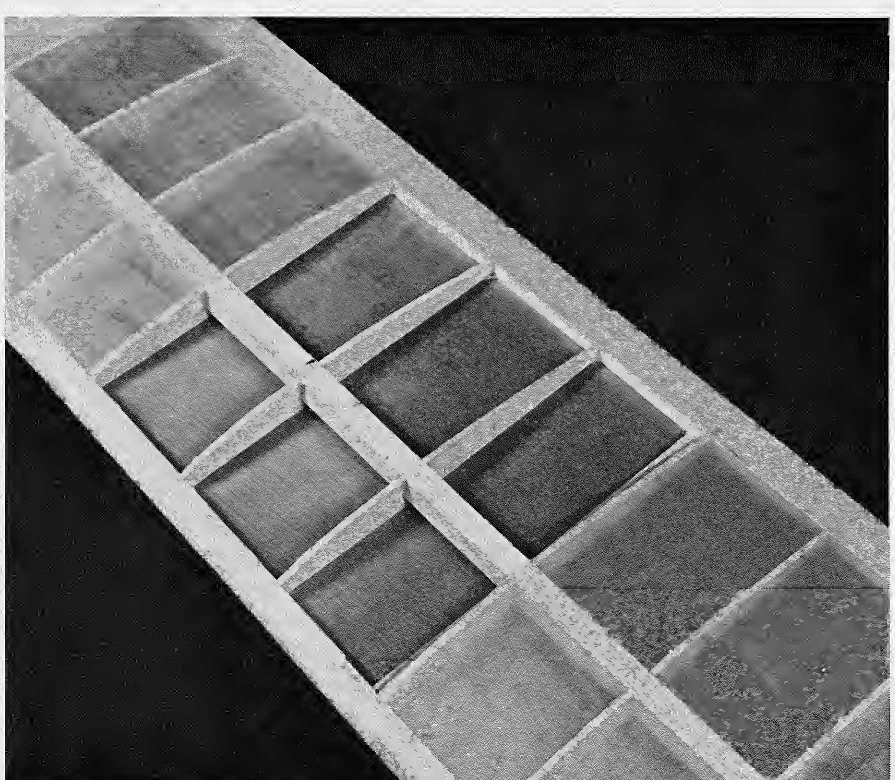
Silk comes in different weights and thicknesses. While any model can be neatly covered with lightweight silk, larger models so covered will be more subject to damage.

Nylon is stronger than silk and is available in various weights. It is not an organic material, but a plastic. It requires more doping than silk to fill the pores and, when applied wet (water), it dries more quickly. Although you must work faster when wet-covering with nylon, the material can always be rewetted as necessary. It is virtually puncture-proof. It should be used on larger planes — though silk is acceptable, if not common — and for hull exteriors. Although heavier than silk and not quite as easy to apply, nylon is not troublesome to work with.

Fiber glass, although not truly a covering material, is nevertheless quite frequently used to cover critical areas — such as airplane noses and cowls and boat hulls. Its terrific hardness greatly increases strength and resistance to abrasion, but always at a rapid increase in weight in an aircraft. For boats the weight is meaningless. Fiber glass is glass cloth, available in various thicknesses, which is applied with a special resin liquid. When hardened it can be sanded, but not easily.

One problem is surface roughness. This can be minimized by temporarily wrapping or covering the wet fiberglassed area with Reynolds wrap or foil, or Saran wrap so that the material can be rubbed smooth, working out bubbles and excess resin. Fiber glass is readily molded. When molded, the surface adjacent to the surface of the mold will be smoothest. Therefore, a female mold (as for a cowl piece, fuselage shell, etc.) will result in the outer surface of the part being smooth. The male molded piece results in a smooth inner surface. Fiberglass panels and sheets can be laid up on glass, then laminated together with epoxy resin using a mold or form. Glass cloth tape is epoxied over the seams.

Molds can be made of wood, plaster of paris (prestressed with wire mesh screening, chicken wire, etc., if mold is large) and other convenient mate-



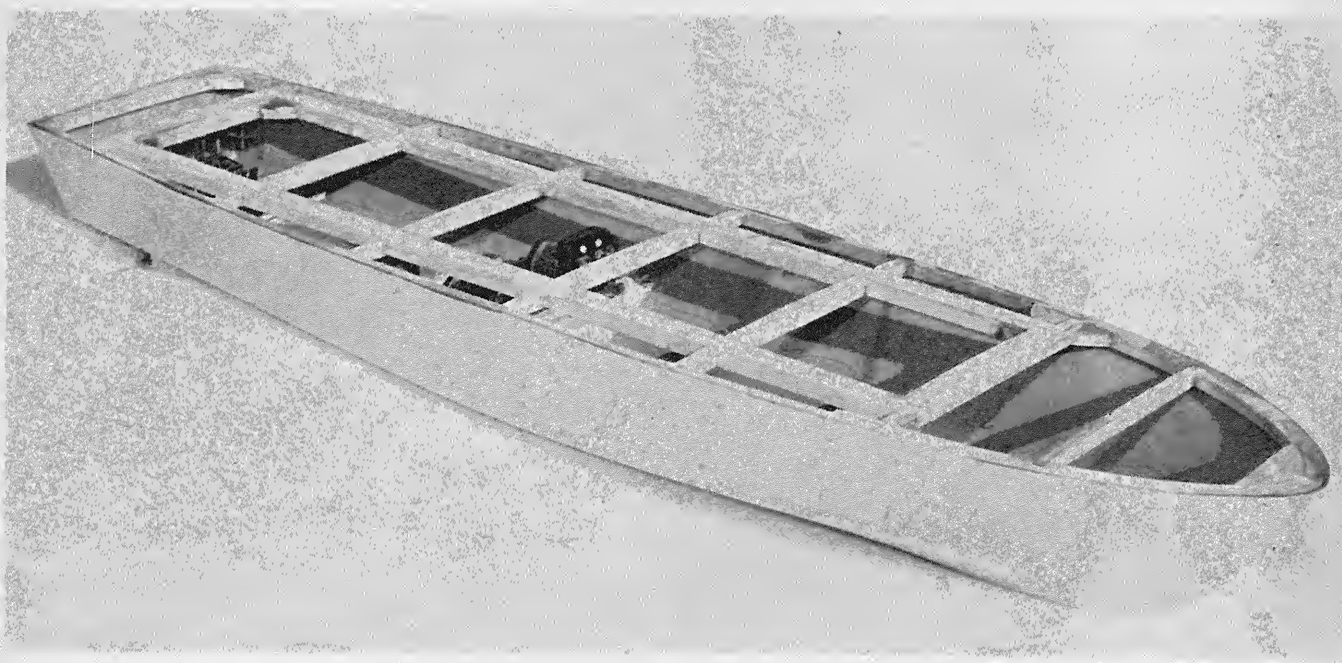
Single-spar wing with section of covering removed to show simple construction. Leading and trailing edges shaped in kit — an Aero.

rials. The working surface of the mold is coated with wax to prevent sticking of the material to the mold. In molding, laminations of glass cloth are built up to the required thickness and strength. Fiberglass shells (Fig. 3-3) make almost indistructible fuselage and boat hull shells. Flanges, mounting blocks, motor mounts, runners, bulkheads, etc., can be epoxied to the shell. Shells permit easy repetition when a number of similar models are to be built. Many airplane and boat clubs organize production-line building sessions.

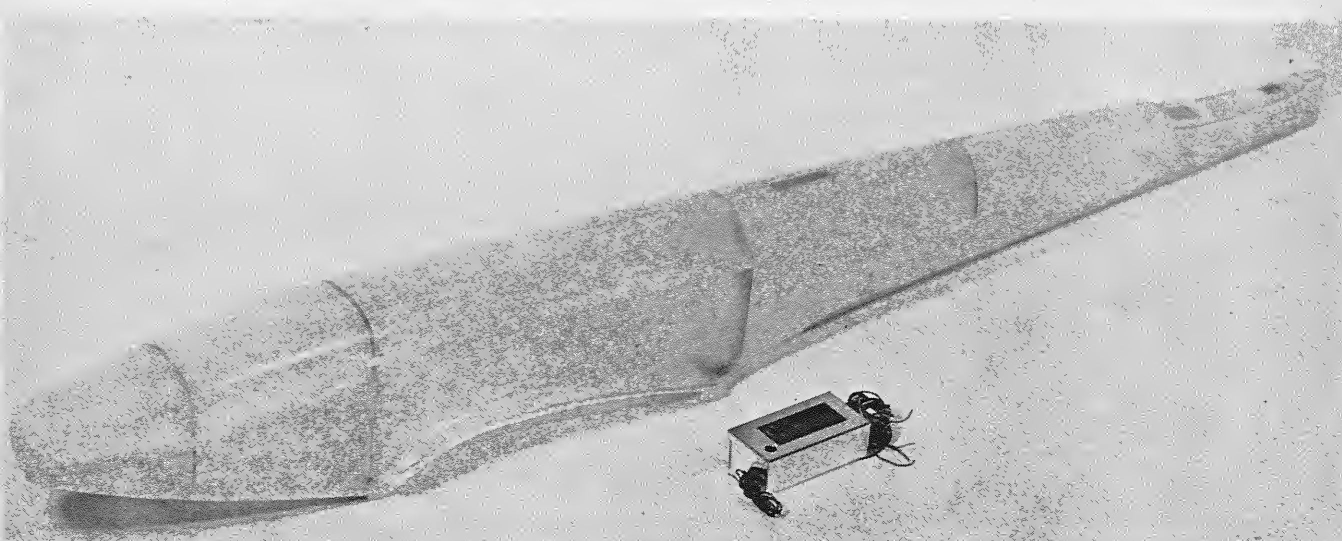
Dopes and thinners: Several families of dope exist. Most common to model aircraft is butyrate, although nitrate dope also is frequently used. Butyrate dope is fire-resistant (though not fireproof) — compared to nitrate dope it has a far slower burning rate. It is fuel-resistant. Model airplane dopes are mixed by the manufacturer to a consistency judged best for the purpose and often contain a plasticizing agent which somewhat reduces their stretching power when drying. (In a lightweight airframe, warping from dope "pull" is a constant problem.)

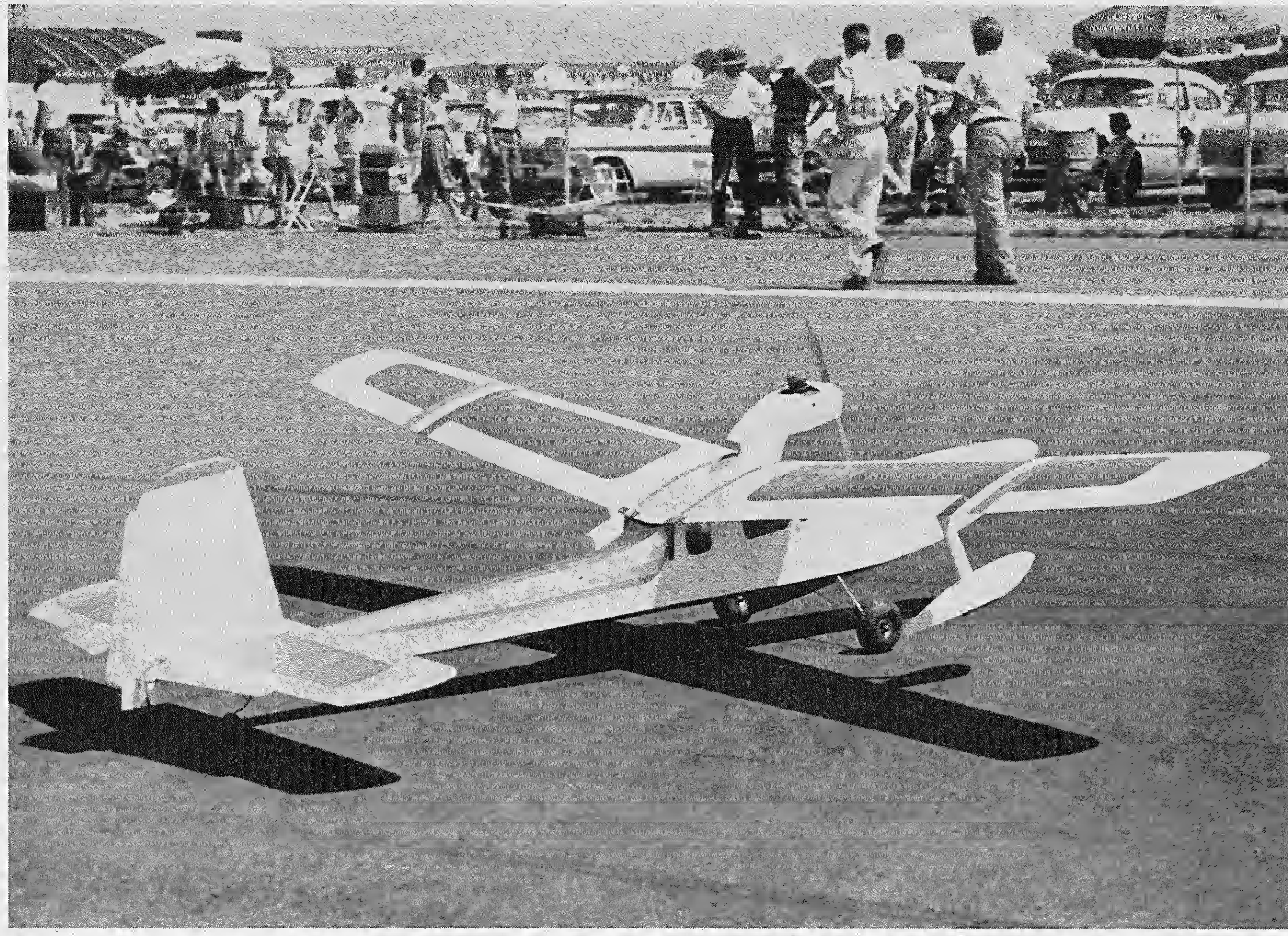
Regular aircraft dopes (for real planes) are full strength and require thinning with appropriate thinner: butyrate thinner for butyrate dope, etc. However, hobby shop dopes usually require no thinning except after some use and standing, or for easier brushing and spraying of colored dopes. Various brands of dope are not always compatible, even when of the same family. Nor are butyrate and nitrate dopes compatible. Nitrate dope can be applied first, with a final one or two coats of butyrate — nitrate is not fuel-proof and requires coverage with a fuel-proofing mixture when used alone. However, nitrate does not work well over butyrate.

When different brands are mixed, the results are much the same. Colored dope may peel off in large pieces and the finish will be dull and uneven. Use one brand name throughout a project. Slightly thickened dope (old dope) is best for applying edges of covering to framework. The number of coats applied over the entire surface depends on the material and the finish desired. Where weight is a factor, two to three coats of clear dope over all should suffice on Jap tissue, three to four on Silkspan, four to six on silk and nylon. (Colored dope is extra.) If material is not well sealed, pinholes will remain over wood areas when colored dope is added. Clear-dope-only is common airplane treatment when colored (dyed) silk is



3-3 **Molded fiberglass hulls and fuselages are found in some kits, or as items available for custombuilding. The hull here is partially assembled with deck frame epoxied to hull. The fuselage is Zeus for multicontrol stunt airplane.**





This huge flying boat has a span of 12 feet and is powered by a .59 cubic inch displacement engine. It uses six radio channels: two channels for rudder, two channels for elevator trim, and two channels for engine throttle.

available — especially for small craft where the added weight of colored dope is a handicap. Clear dope alone will show damaging effects of sun and weather much sooner than will colored dope — not a serious factor, really, unless the vehicle is old or has been in the open over a period of time. With age, an airplane may require a yearly coat or two of clear dope when dyed covering is used. Clear dope can be brushed or sprayed. The spray gun is desirable when large areas are to be doped.

Colored dopes also can be brushed or sprayed on, and they come in regular cans and bottles, and in spray cans. Inexpensive small spray guns can be bought in hobby shops, paint stores, and hardware stores. The spray can is fine for models that are not too big, but it is relatively costly for multicoating large areas; here, regular dope in bulk, used with a spray gun, will prove more economical. In ordinary usage, two to three coats of sprayed-on color is adequate, but some builders—as for scale aircraft, or boats —may use as many as 12 coats, sanded between coats with wet-and-dry papers, the final coat rubbed and waxed. (We do not include here base coats on wood, fillers, or clear dopes.) For spraying with a regular gun, colored dope should be thinned as directed, usually by 20 per cent or more. For brushing colored dopes, add 10 per cent thinner.

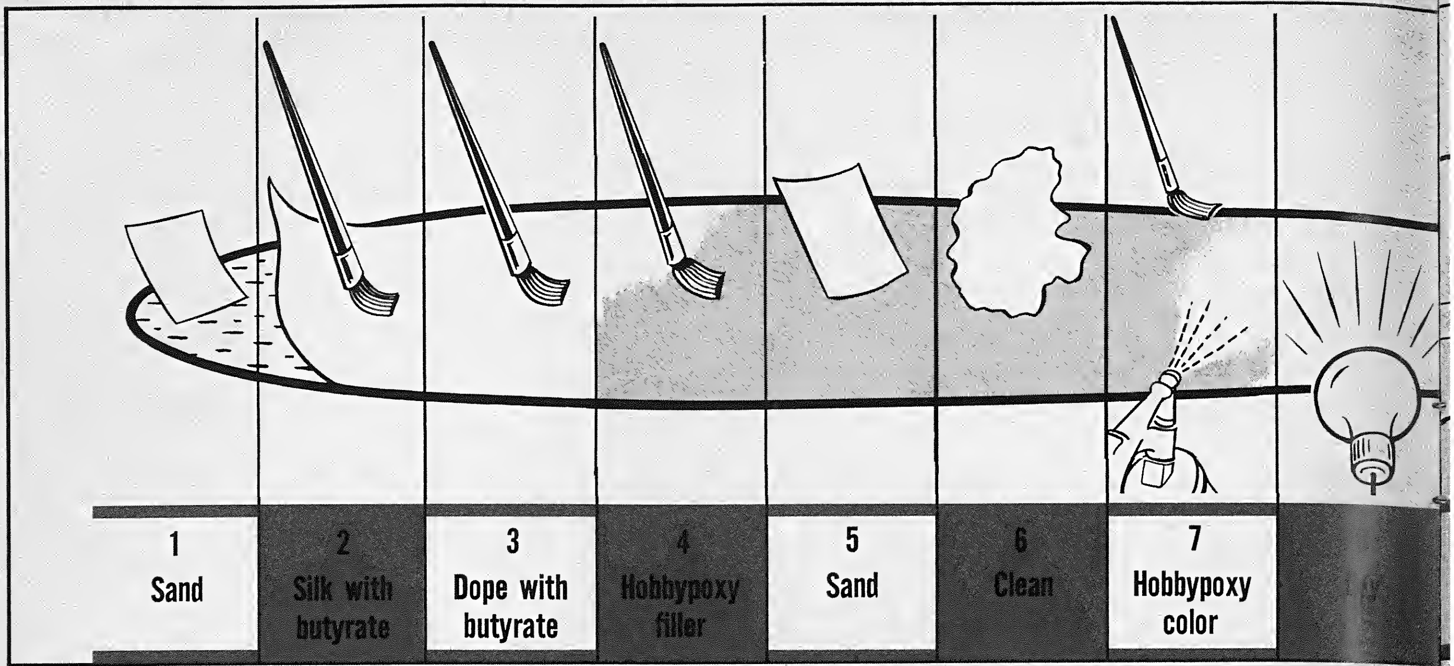
Sharp definition lines in multicolored designs are achieved with masking tape. The tape edge which controls the paint line should be pressed down evenly, then, in the case of airplane dope, given a coat of clear dope. This prevents all bleeding of the darker color under the tape edge. Allow dope or paint to dry thoroughly before removing the tape. The tape should be pulled off at an acute angle back upon itself, and not straight up — this sometimes lifts thin lines or even pieces of the top color. Hobby, stationery, hardware and paint stores all carry various kinds of trim tapes in many widths and colors: these are applied directly to the surface in lieu of colored dope or paint. Hobby shops stock a wide selection of decals and decal solid-color material which can be cut to desired shapes.

Unsightly random fillets often result when colored dope is brushed over fin and fuselage junctions and similar places, because the dope softens the cement beneath. This can be prevented by brushing epoxy resin over the glued joint to protect it against the softening action of colored finishes.

"Dry brushing" is another method to prevent the lifting of colored dope fillets. After dipping the brush in the colored dope, excess dope is brushed out upon a bare surface; then the remainder is painted on. Or, the colored dope can be thinned as much as 50-50; then repeated coats can be applied to obtain the solid color required, allowing each coat to dry first.

Good brushes are essential because dope easily pulls hair from ordinary brushes. Ox-hair brushes have bristles pliable enough to withstand constant usage without shedding. No brush will stand up unless it is cleaned immediately after usage (with appropriate thinner) and kept soft.

Epoxy paints: Epoxy clear and colored "dopes" will bring out the shine and greatly strengthen the surface. Epoxy clear and colored paints — Pettit's Hobbypoxy fuel-proof finishes are distributed in hobby shops—can be used over model airplane doped finishes. Since the epoxy finish takes up to 24 hours to dry hard, it is important



3-4 **Chart illustrates sequence of operations in application of Hobbypoxy finish.**

to work in a dust-free place. Such paints have great covering power, so a small quantity goes a long way. An appropriate thinner is sold with both clear and colored epoxy finishes at hobby shops which stock such items. (Fig. 3-4.)

Marine paints and enamels: Many hobbyists use standard enamels and lacquers. However, even though the builder may not use a glow fuel, the model may come into contact with exhaust from another model, or may be handled with fingers moist with fuel — damage can result. But if these objections do not exist, such materials suffice. Special enamels and lacquers are sold in the better hobby shops.

It is always important to use the proper type of modeling paint or finish for the particular modeling category — aircraft dopes for planes, marine enamels for boats, appropriate liquids for plastic models. In plastics particularly, the structural material can interact with either cement or paint. The characteristics and qualities of the finish should be appropriate to the use — lightness, flexibility, hard or glossy finish, etc. Of course, there is much cross usage of paints, such as airplane dopes on boats. Epoxy paints are excellent for boats.

Several references are made to the importance of fiber glass on a boat hull to protect it from damage during transportation, or from obstacles on or under the water, and along the shore. For the most efficient bond of the glass cloth to the wood hull, the resin should be applied to the raw wood. An epoxy paint must be used for final finishing if there is to be a permanent bond to the undercoat.

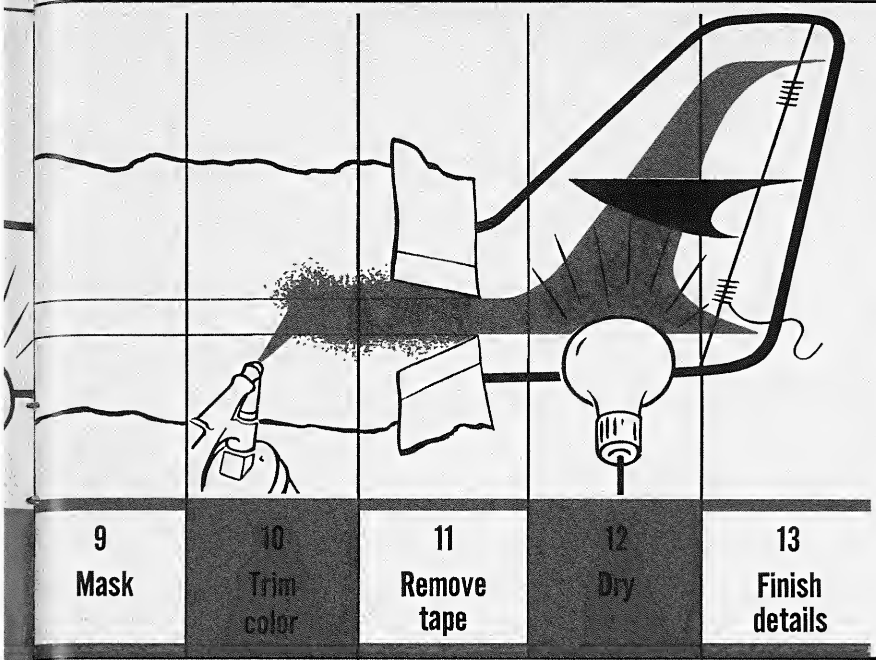
Wood sealers and fillers: To be distinguished from plastic woods, balsa putty, plastic balsa, etc. (which are used to fill large crevices or to mold shapes such as fillets), fillers and sealers are intended to achieve a smooth surface prior to painting. The simplest surface sealer is a homemade mixture of talcum powder and dope, mixed to a creamy consistency. It can be brushed or rubbed on to fill surface pores; if thick, it will fill small nicks, crevices, holes, scratches. After each application of this material, the surface is sanded again with fine paper, or wet-and-dry, until the high spots show through as bare wood. Eventually, application of enough coats, each followed by a sanding, produces a painting base that is glass smooth and opaque, showing no grain marks, etc. The final coat is not sanded. Of finer texture, and better suited to the job, are commercial sanding sealers produced by the model dope manufacturers.

Sealer can be applied over paper or silk — usually which has been applied over wood areas — or can be used on bare wood surfaces such as fuselage sides, boat hulls.

Plastic wood, balsa putty, plastic balsa: All these materials are of thicker consistency than the sealers; they can be used for filling large holes, molding fillets, building up localized areas on wood surfaces to aid final shaping, etc. Although the ingredients differ, they all contain fine wood particles, wood dust, etc., mixed with an adhesive agent; they handle somewhat like putty, but can be worked, sanded, etc. A useful, less perfect mixture can be effected quickly by mixing balsa sawdust or sanding dust with cement. As with sealers, cements or dopes, a test should be made for compatibility between the plastic balsa, etc., and other liquids to be used over the molded or filled-in part.

Balsa: A lightweight tropical wood, balsa should be selected for grain and density according to the proposed use, and according to the individual component. The density of balsa varies greatly; lighter varieties are useful only for indoor-type models. (Fig. 3-5 shows the use of balsa in an airplane.) Depending on the portion of the log from which the plank, then the strips or sheet, were cut, sheet balsa particularly will have important differences in grain characteristics. Some sheet bends readily along the grain line, and some feels stiff and resistant to this bending — it will split along the grain if bent. If it is to be used for curved parts — leading-edge section covering, for instance — sheet is selected for pliability. The rounded pilothouse of a small boat, or the hood of a car, could be made of such wood. Acute bending, or bending of thicker sections, will be aided by briefly soaking the wood in hot water.

Balsa strips ordinarily are cut to needed lengths with a single-edge razor blade or balsa knife — larger sizes, by a Stanley knife. Since it is difficult to make a true cut in thicker pieces — the trouble begins at about ¼″ square — a fine-toothed saw yields consistent accuracy. Sheet balsa parts are cut with the same sharp-edged tools, but curved cuts will require a narrow blade. For small work, a sliver can be broken from a single-edge blade; for larger work, the appropriately shaped blade for a balsa knife is better. In cutting thicker



ABC'S OF USING HOBBYPOXY

	Step 1	Step 2	Step 3
BALSA — 1 Lightweight — without silk	A	B	C
BALSA — 2 Medium to heavy — without silk	B	C	
SILK — 1 Over balsa including open areas of wing	D	B	C
SILK — 2 (dyed) Where only Hobbypoxy clear is used on open areas	D	A	

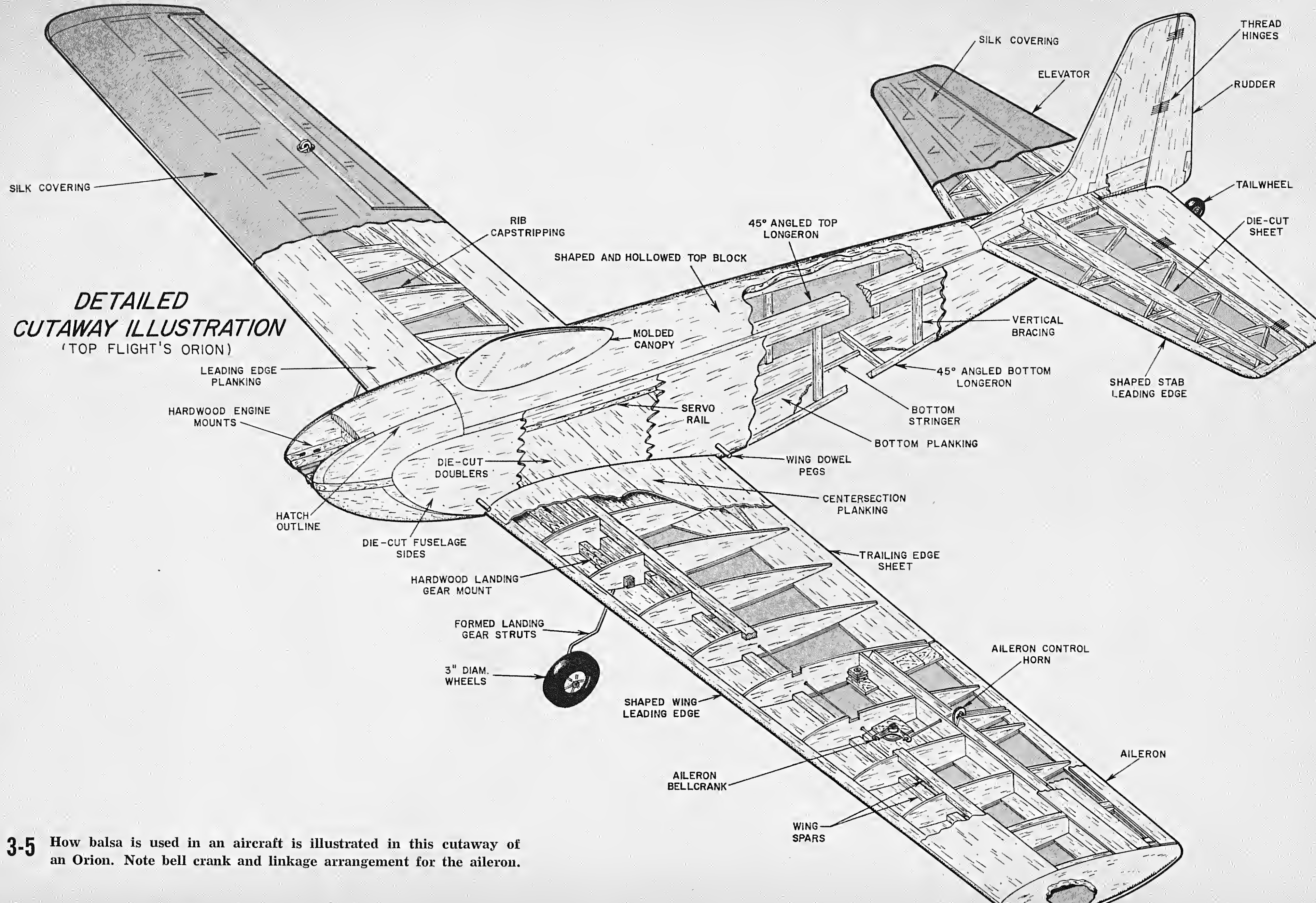
A—Hobbypoxy clear **B**—Hobbypoxy filler
C—Hobbypoxy color **D**—Butyrate clear

pieces of sheet balsa, a metal straightedge should always be used as a guide, and repeated long but light cuts should be made, using as many cuts as necessary to part the wood. For structural shapes, cuts should be made slightly outside the line; then the wood can be brought down to size and an accurate edge by dressing with a sandpaper tool.

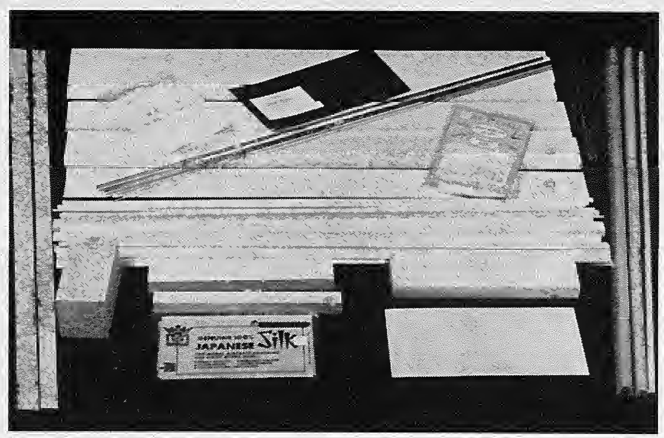
For ribs, sheet balsa should be stiff. Sheeting used for trailing edges, etc., should be quite hard and resistant to either bending or bowing. In general, where weight is not a factor and strength in load-carrying members is required, harder, stiffer wood should be selected. Soft wood is good for shaping blocks, etc., where weight must be held down. While balsa in any form is easily cut, shaped, hollowed and smoothed with anything from razor blade or Stanley knife to coping saw or small hobby wood plane, care must always be taken that the material is protected from damage while it is being worked. This soft wood is easily marked by dried glue bumps on a bench top, buttons on a shirt, a ring, watchband, etc. Always clear the work area first, including a rough sanding of the work board on which wood will be cut or sanded. If working with gouges, etc., place the wood on a protective cloth, especially if the block has been exteriorly shaped prior to hollowing.

Sight along strip and sheet wood to check for bowing. Thin sections stored vertically for a long period may acquire a permanent bend, or the plank from which sheet balsa was cut may have been bent in storage. Sheet balsa pieces to be butt-joined together should be picked for straight edges which fit evenly together. Lack of

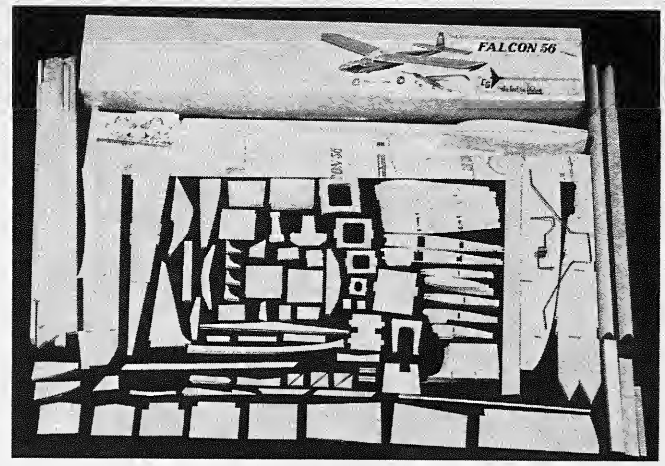
An original-design seagoing navy tug. Note figures: officers on bridge, signalman, etc.



3-5 How balsa is used in an aircraft is illustrated in this cutaway of an Orion. Note bell crank and linkage arrangement for the aileron.



Representative samples of wood and other materials. At left are shaped trailing edges; at right, shaped leading edges. In foreground, silk in package, blocks of balsa, sheet of plywood. At rear, nylon, sheet brass, glass cloth, steel wire in five sizes.



These are the parts contained in a typical medium-sized airplane kit for optional use of from one channel through six channels of control. Notice the formed wire parts.

straight, true edges makes difficult the assembling of fuselage sides, or boat hulls, where various widths of wood must be joined side by side.

To true up such wood, rule on the desired true edge, then sand or trim with a sharp tool (Stanley knife or balsa knife), using a steel rule for a guide. C clamps can be used, if necessary, to hold the wood and guide in position adjacent to the bench edge. If the wood is jigged flat on the bench with the portions to be removed overlapping the edge of the bench, the excess material can be eliminated with long strokes of a sanding board or tool.

In assembling fuselage sides, etc., from parallel pieces of sheet, arrange each side so that the portion which was adjacent to the working surface becomes an outside surface on the finished model. This avoids excessive sanding and prevents weak spots from reducing wood of varying thickness, or seams, to a common thickness and a smooth surface.

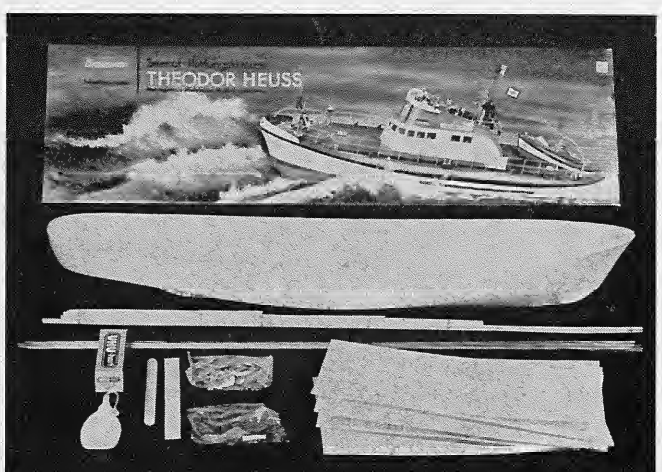
Balsa requires careful sanding. It is so easily sanded that critical mistakes are quickly made. A sanding tool with large surface area avoids localized pressure, whereas sanding with small pieces of paper held in the fingers creates depressions and grooves in the wood from fingertip pressure — even nicks from nails. Strips—such as trailing-edge pieces — should be sanded alternately on each side, not fully sanded on one side first, as this causes bowing due to compression of the fibers. Butt ends, squared-off blocks, etc., can be positioned at the bench edge — which serves as a jig — for uniform sanding with the proper tool.

Variously shaped sanding tools can be made from pieces of plywood, half-round blocks, dowels, etc., with the desired grade of paper attached smoothly with contact cement.

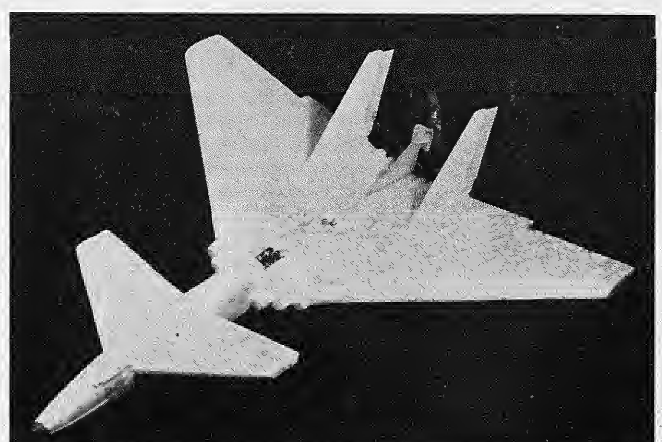
The reader who has power tools, or at least a circular saw, may elect to send away to a hobby mail-order house dealing in balsa to obtain planks of specified hardness which can be cut economically into sheet, strips and blocks of convenient dimensions. The saw blade should be suited to cutting softwood. A belt sander is a great help to the hobbyist.

Plywoods and veneers: Plywood is used for highly stressed parts such as firewalls, engine mounting bulkheads, nose doublers, landing gear mounting plates, car chassis, boat bulkheads, etc. Normal thicknesses are 1/16", 3/32", 1/8", 3/16" and 1/4". Aircraft-grade plywood is preferred for the quality of the wood, bonding and number of laminations. Cheaper grades are pithy inside, are coarse grained and given to jagged tearing when sawing. Birch ply is commonly used for modeling. Veneer usually is mahogany. Both thin plywood and veneer are used for reinforcing large balsa areas — rather like doublers—for builtup vehicle and boat superstructures, etc. Large pieces of balsa and ply or veneer which are to be laminated are joined with contact cement. Hobby shops handle convenient sizes of plywood, but very large pieces of ply and veneer are lumberyard items.

Other hardwoods: In nonflying craft, the weight of hardwood is not



This imported boat kit is significant for its ready-formed styrofoam hull. Printed plywood parts are in the right foreground.



Another styrofoam product, a B-70 kite, is here converted to a powered (pusher) radio-control airplane. Notice the hole in the fuselage (hatch removed) for radio.

German multicontrol plane which tied for first in the 1963 World Championships, by Fritz Bosch. Power is .56-size engine. Wing is shaped from styrofoam blocks with wood spar and thin wood covering.

an objection. Basswood, for example, has an even grain suitable for carving. Maple makes strong motor mounts and engine bearers. Pine is used in many areas, even in aircraft for servo bearers, etc. Laminated, pine is good for boat hulls and other types of bodies which are carved to shape. Spruce (in smaller cross sections, of course) makes excellent spars for multicontrol aircraft. Many hobby shops stock all these materials; some have racks of variously sized spruce, just as they do balsa.

Steel wire: Also called music wire or piano wire, steel wire comes in graduated sizes up to 5/32" diameter at hobby shops. While some sizes are designated usually as decimals, common usage has made popular these inch diameters: 1/32, 1/16, 3/32, 1/8 and 5/32. Steel wire will vary in hardness and bending characteristics, some being brittle, some rather soft. Generally, a consistent quality of wire is sold as a separate item in hobby shops, but wire that comes in kits shows most variations. Good kits usually have wire of the proper qualities. You may wish to buy replacement wire and bend the parts yourself. However, difficult-to-bend parts, such as shock-absorbing nose-wheel struts, cannot be bent without a special jig.

Most commonly used for landing gears, formed music wire pieces attach to ply mounting plates by means of strap fittings (bolted in place) or J bolts (hobby shop items). Round-nose pliers are used to bend small sizes of wire, but thicker pieces will have to be clamped in a vise and bent with a hammer. Thin sizes can be cut with diagonal pliers, electrician's pliers, etc., but larger sizes should be filed off.

Steel wire is easily soldered — frequently must be soldered. The protective oily film must first be wiped off and any discolored or tarnished surface brightened with fine sandpaper or steel wool. The portion to be soldered can be tinned after rubbing with soldering paste. A hot iron is a must. However, even a 37-ohm chisel-tip pencil iron of about 1/4" width will be capable of soldering even 1/8" wire. When two heavy wire pieces are joined for a highly stressed joint, as in a landing gear, the joint also is wrapped with thin wire which will accept solder, and solder then is flowed into the crevices. The surface can be filed smooth. (A stiff wire brush cleans the file teeth.)

Occasionally, washers must be soldered over wire — to retain wheels, or a cam follower on an escapement, etc. — and controlled spacing is required between washer and part; or a part is to be protected from contact with the iron. Make temporary spacers from appropriately sized sheet balsa, drilling a hole to slide the spacer over the wire. By holding the work vertically, the spacer and washer will rest evenly, and solder can be applied. Afterwards, split the balsa and remove it. If soldering is performed adjacent to a shaft and bearing, a drop of oil should be placed on the shaft to avoid any possibility of flux freezing the bearing.

Styrofoam: This featherweight material is finding increasing usage, both in molded form commercially for fuselages, hulls and even complete vehicles, and for original use by individual builders who cut shapes from blocks by means of a "hot" wire. The cutting tool is usually a .004" chromolux wire stretched like the string of a bow between two stiff wire arms on the ends of the wood "bow." The desired degree of heat is obtained by varying the resistance in the wire circuit by means of a rheostat, etc. Plywood profiles of the end shapes of the block to be cut are fastened to the material, and the wire bow is drawn over these guides.

Usually, the foam wing is covered with thin sheet balsa, applied with white glue or a special contact cement (no volatile adhesives can be used). Detailed articles have appeared in the magazines, notably the June 1964 *Model Airplane News.*

Miscellaneous: Your dealer is well stocked with parts and accessories which can be considered materials. Several manufacturers, for example, package dozens of small items — machine screws, blind nuts, Micarta pieces, nylon cord, soldering lugs, bushings, etc. — in transparent packages displayed on racks. If you are making a model for the first time, it would be good to familiarize yourself with the many things which can make your work easier, and your models better.

4: CONTROL SYSTEMS

THE means by which common full-scale vehicles are controlled are widely known. An airplane is maneuvered by means of a rudder, elevators, ailerons and throttle. Our models may have such auxiliary controls as up-and-down elevator trim, wing flaps, wheel brakes — but the primary aerodynamic controls are those which rotate the aircraft about its three axes: the yaw axis (rudder), roll axis (ailerons) and pitch axis (elevators). While engine control is essential to all real powered aircraft, in a glider the "engine" is gravity. Most simple planes can do without engine control without harm.

Given certain design features, the radio-controlled model aircraft can be operated without any control but rudder. (Fig. 4-1.) Or, between the extreme of "full house" (that is, all primary controls) and rudder-only, it can be operated by a compromise arrangement determined by the wish for the ultimate system on the one hand, and practical limitations of cost and complexity on the other. Thus, in many dynamic R/C models of any kind — ground, air, or marine — controls frequently are more limited than on the real-life machine. However, when an "ultimate" craft is not feasible, quite satisfactory and surprising results can be obtained with rudimentary systems.

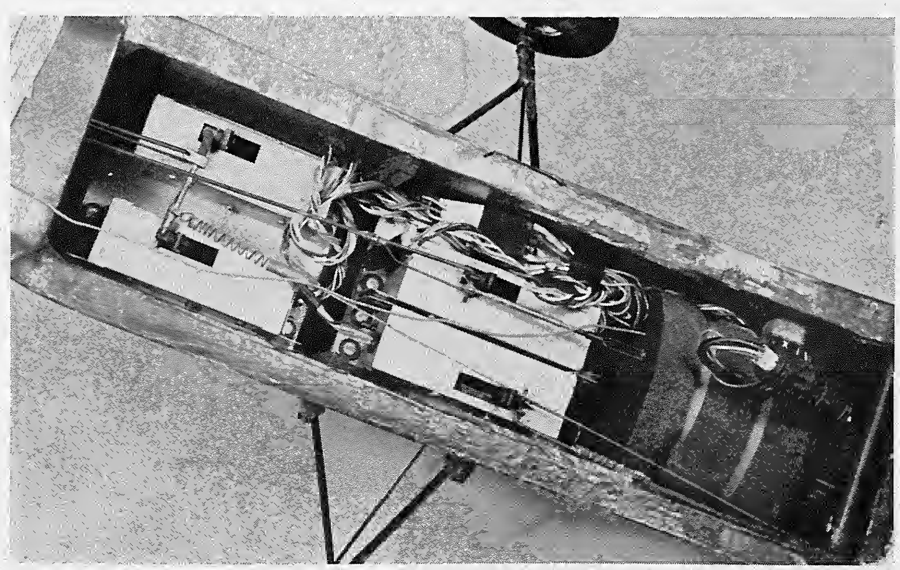
Most marine vehicles require fewer controls, but due to conditions inherent to boats, auxiliary functions may be many. Boat fans like to add many operable gadgets. Basically, a boat requires only a rudder control to steer by, but if it is to have utility it must include provision for controlling the power of the electric motor or gas engine which propels it.

Ground vehicles — cars, trucks, tanks, and so on — have basically similar requirements. Steering is primary, but engine or motor control always is desirable — virtually imperative if running speed is not very slow. Without power control — including stop and reverse in electric motors — the vehicle is not very practical. Beyond the premise that a plane, boat or car can be remotely controlled by steering alone — but that other primary and auxiliary controls can be added in numerous combinations — the new hobbyist is bewildered by many beckoning possibilities. What he might wish to do will be tempered by conflicting requirements in design and purpose, influencing his choice of equipment.

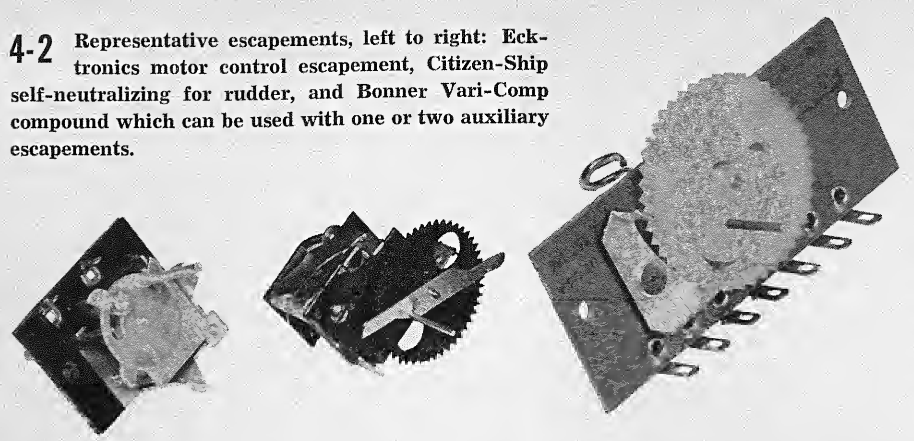
Steering, we have said, is a common denominator to all model vehicles. It is obvious that, unlike submarines or airplanes, a landcraft can't dive or climb as a result of control movement, being able to maneuver in only one geometric plane. Both sub and plane are more or less capable of maneuvering in space.

Although the airplane is three-dimensional in its operation, it is only in the fully aerobatic model that rudder as the only primary control is not adequate. Model R/C airplanes are di-

4-1 **A simple single-channel system: Bonner SN escapement in fuselage; transistorized relayless receiver, right foreground; rechargeable nickel-cadmium batteries for a common power supply. Escapement's drive rubber attaches to hook behind escapement.**



Typical servo installation in Citation: Left, top, elevator servo; bottom, elevator trim servo. Center, top, rudder servo with arm extending forward to lever arrangement to steer nose-wheel strut; bottom, engine control. Coil spring on trim servo attaches to monofilament line which actuates wheel brakes. Receiver is wrapped in foam rubber at right.



4-2 **Representative escapements, left to right: Ecktronics motor control escapement, Citizen-Ship self-neutralizing for rudder, and Bonner Vari-Comp compound which can be used with one or two auxiliary escapements.**

vided into three classes for competition purposes: class 1, controllable about the yaw axis (requires rudder); class 2, controllable about the yaw and pitch axes (requires rudder and elevator); and class 3, controllable about the yaw, pitch and roll axes (requires rudder, elevator and ailerons). Throttle is an auxiliary permitted to all classes of model planes. The plane can be controlled about three axes; the sub is limited to yaw and pitch control by practical considerations.

Simple control systems should not be underestimated. The plane that flies by rudder only is capable of loops, rolls and other "stunts" with just this single control. Steering, whether it be the simple left-right movements of an airplane rudder or the selective action of caterpillar treads on a tank or dozer, is the most commonly used, and surprisingly flexible, control — and serves to outline the fundamental conditions which influence our choice of equipment.

It is immediately apparent that many systems, and almost infinite variations thereof, provide steering capability. Some are more suited for this or that type of vehicle. Within each system, there are options to consider carefully.

The work load placed on the actuating mechanism — servo, escapement, etc. — may be inconsequential in some cases, extremely demanding in others. The rudder on a 2-foot airplane requires very little force to be displaced to the right or left. The rudder on a boat, however, working in a heavier medium (water cannot be compressed like air), requires more muscle for actuation. A caterpillar-tread tractor cannot be steered easily with an actuating device that would operate the rudder on a plane or boat. Here, switching on and off of separate electric drive motors appears one feasible solution. Vehicle size and speed varies the work load with each type of craft. Thus, control system requirements, even for just one control, are variable within each type of vehicle.

If we consider that there are two popular types of actuators — those devices which displace or move steering controls — we quickly discover other useful clues to the over-all system best suited to a particular model and situation.

Consider the pros and cons of escapements versus servos. An escapement (Figs. 4-2 and 4-3) may be suitable for simple small-to-medium-sized airplanes, but it is totally unsatisfactory for a large, heavy, or powerful machine. When used in boats for primary control it is generally useless in any but the very smallest and slowest.

Environment is more than the medium in which the vehicle operates, although medium is the background against which all problems are constantly evaluated. Vibration, for example, is an important environmental problem. Rough-running engines in an airplane can cause an escapement to skip (or create subtle problems in all forms of flying), giving wrong and perhaps fatal control movements, or ineffective control. A fast-turning small engine in a tiny plane can reach a resonant vibration with the movable armature of an escapement (or of a relay), causing erratic control.

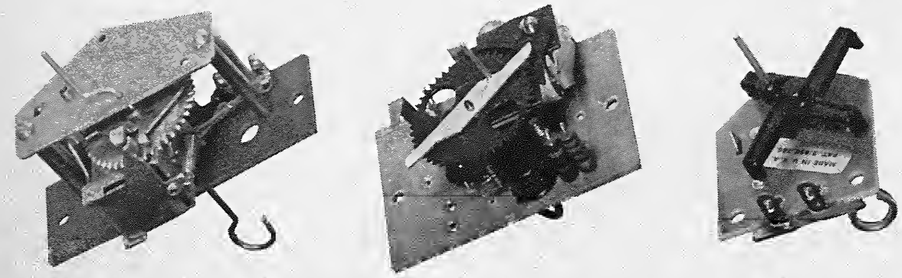
In advanced systems which use multichannel relayless radios with electric-motor-driven servos, vibration requires such precautions as soft mounting and correct positioning of receivers. For instance, it is a wise practice to position receivers so that the movement of the reeds in a reed bank does not correspond with the direction of movement of the engine's piston. Reliable control is impossible when any system is vulnerable to vibration.

Time is an environmental factor. Our steering mechanism has a natural operational cycle period which must be suited to the type of vehicle. A slow-moving rudder on an airplane will cause an accident. Quick response and neutralization are vital. On most boats — excepting racing varieties — rudder response time need not be short. Neutralization can be slower, or may not be required at all. The same thing applies to ground vehicles.

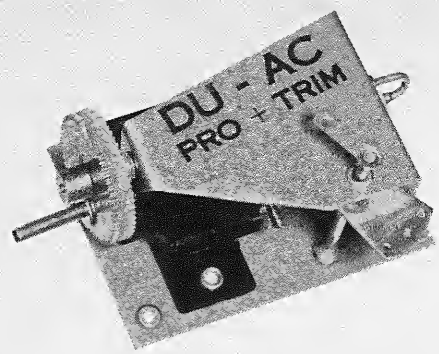
Illustrating these conflicting requirements is an illustration in the Bonner Vari-Comp escapement literature. One variation shows the escapement as a switcher which causes a metal arm to make and break two contacts which, in turn, control polarity to a servo motor to drive it to, or toward, either of its full-control positions. This switcher setup is feasible in a limited way for boats or cars, but is not particularly useful for aircraft. As a switcher it applies the servo's power to overcome high control forces when speed of operation is not a handicap. (Refinements of this principle are explained in chapter 7 on Boats.)

Timing also is related to the speed of control of the keying system at the transmitter, since response of the vehicle is affected. As an extreme example, a telephone dialing-type system — occasionally seen in a slow boat having numerous auxiliary functions — is undesirable in an aircraft. Here it has many handicaps, the most serious being an inability to instantly obtain the desired control movement. It is sequential rather than selective. This business of sequence and/or selective controls has bearing upon everything we do.

Over and above these considerations, there are different techniques by which a control can be moved, and all of these techniques have characteristics which determine their eligibility for particular applications. For instance, do you move the rudder all



4-3 **Left to right: Babcock Mk II compound escapement, Citizen-Ship transistorized escapement (steps up voltage for escapement and "quick blip" motor control with relayless receiver), and Bonner SN for rudder on small planes or motor control.**



Typical motor-driven actuator for single-channel proportional when planes are too large for little magnetic actuators.

at once — in a gulp, so to speak? Or do you move it progressively and smoothly?

In aircraft, popular terminology describes this varying nature of the movement of a control surface. One that moves abruptly and fully from neutral to the full-control position, and returns to neutral in the same manner, is termed "bang-bang." One that moves smoothly to any desired position between neutral and full control—it also can be moved abruptly to full control and back to neutral — is "proportional." Derived from proportional is "trim," in which the movement is slowed down and the neutralization ability removed—making the control positionable. Proportional, in which the actuator(s) slaves to the movement of the transmitting device — stick or wheel, etc. — should not be confused with positionable, or trim.

Positionable controls, that can be set anywhere between neutral and full-travel, play important roles. Engine throttling on any vehicle can be positioned between low and high power to maintain a desired running or flying speed. Elevator trim — in addition to full control movements — in an airplane is similarly positionable, up or down. Many slower boats and cars have positionable qualities in their primary control — steering. If the boat so equipped is steered in a circle of any desired diameter it will maintain that circle until either more or less turn is imparted by some adjustment to its positionable actuator through appropriate commands. It is extremely difficult, on the other hand, to operate an airplane with positionable controls. Even in proportional systems, aircraft and fast ground and marine vehicles require fast-acting neutralization.

An escapement is "all or nothing" in its responses. So is the self-neutralizing servo used for "multi" primary controls, as distinguished from the various proportional servos. Repeated brief control signals (done by "pulsing" a lever switch with the hand) to a self-neutralizing servo do impart a rough simulation of proportional action in that the repeated movements of the servo from neutral toward the control position give an average application, but such operating techniques rarely approach true proportional in smoothness.

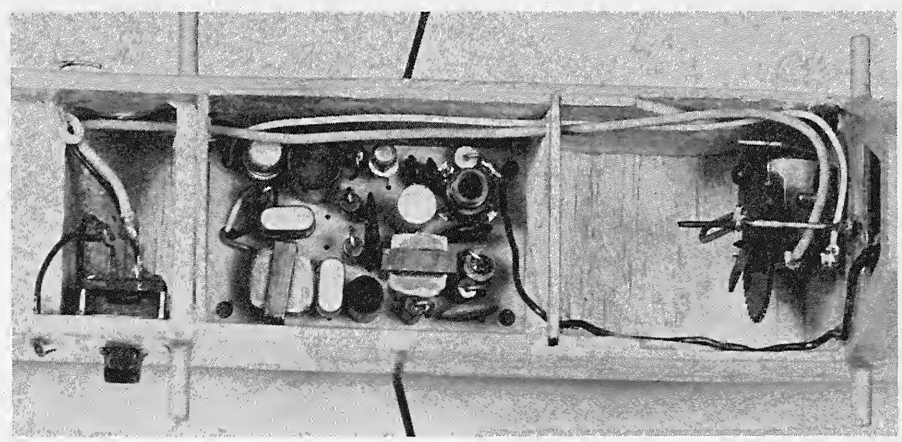
Various proportional systems exist by which signals are electronically "pulsed," sometimes in rate, sometimes in length, and sometimes variations of both rate and length. In a simple aircraft with rudder-only control, either a magnetic type of actuator (pulse system) or an electric-motor-driven actuator slaves to these special signals, giving a degree of steering that corresponds to the amount of deflection of the control stick or the turning of a control knob on (or connected to) the transmitter.

The single-channel proportional pulser — one example is "Pulsi-Tran," a small unit which attaches to a hand-held transmitter — might vary the on-off time. Equal on-off would be neutral; full on (steady signal) would be full rudder in one direction, and full off (no signal), full rudder in the opposite direction. Obviously, the ratio of on to off can be varied in infinite degrees between neutral and full-off or full-on. The Septallete magnetic actuator, for example, slaves according to the signals caused to be transmitted by the pulser and picked up by the receiver. The actuator, and hence the rudder, always agrees in position with the position of the pulser stick or knob. (Fig. 4-4.)

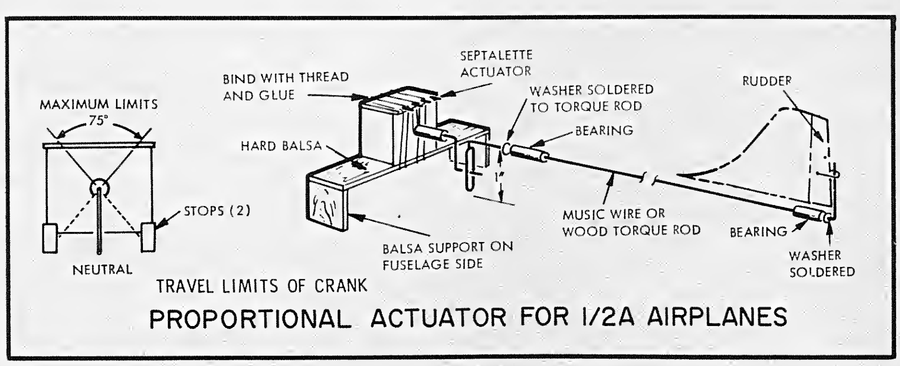
In a multiproportional setup a number of simultaneous tones—two, three, four or even five — are appropriately varied to produce slaving movements of three actuators.

When we say that an actuator is sequential in operation we mean that various controls can be attained in an ordained order, but requiring that previous unwanted control positions be quickly passed through. When we say selective we mean that an actuator has the ability to supply directly the demanded control movement.

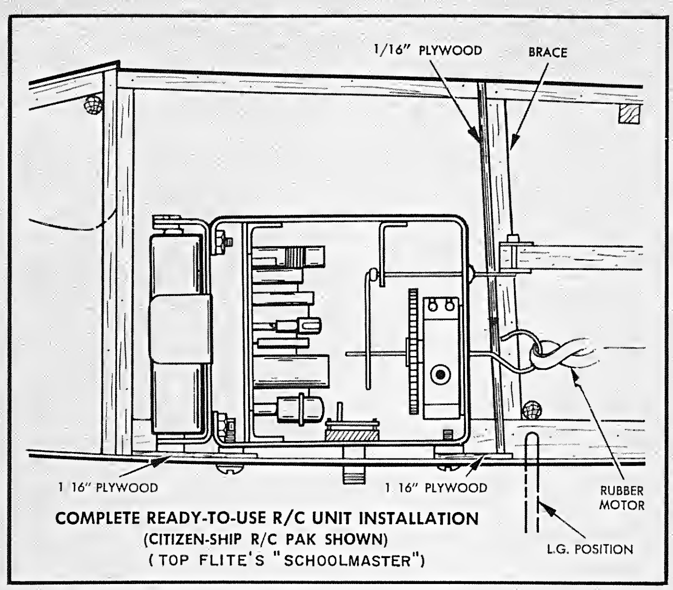
Although some servos and steering machines are sequential, we may roughly classify escapements as sequential, and most servos as selective. What makes most servos selective is that their electric-drive motors are reversible, each servo requiring two channels of radio control — one for each direction (or substitution of some type of switcher as mentioned before). The escapement, however, operates from one radio channel, as do some special servos and steering machines. For the escapement, therefore, a suc-



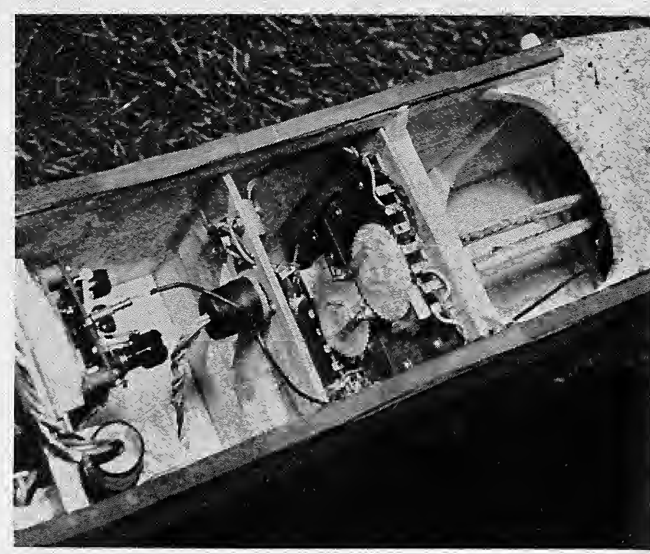
A complete single-channel relayless receiver installation in a tiny .01-powered Veco Pinto plane.



4-4 **Installation of the Septalette magnetic actuator for proportional single-channel control in small planes.**



4-5 Unique Citizen-Ship R/C Pak incorporates receiver, escapement, switch, all wiring in small unit. For small aircraft.



4-6 "Cascaded" escapements: Two Vari-Comps give left-right and up-down, in addition to engine control via an auxiliary escapement operated by a switch in the top Vari-Comp.

cession of transmitted signals is needed for certain operations.

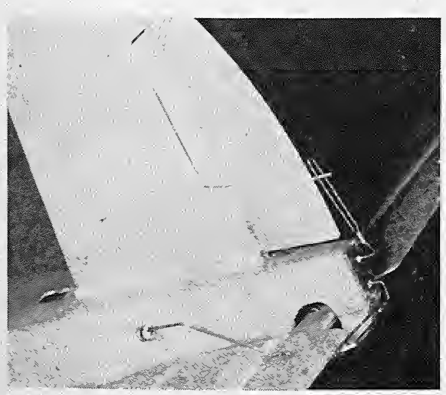
Simple escapements: The simplest type of escapement is the SN — meaning self-neutralizing. (Fig. 4-5.) When a signal is held on, the receiver closes an electrical circuit to the escapement coil, releasing the mechanism to move to a control position. When the signal is relaxed, the escapement returns to neutral — and the control surface with it. The next held signal that releases this escapement causes it to continue its rotation in such manner that the opposite control is picked up — as, say, left rudder after right rudder. Thus, the device is sequential in that the opposite control position always follows the position just occupied. If a repeated control movement is desired, the device must first go through the unwanted position, neutralize, then reach the wanted position, requiring two quickly transmitted signals, the second being held on. This type of escapement is used only for the smallest aircraft primary control.

This nonselective function of the SN escapement imposes a burden on the operator, because it is desirable to remember what position was used last in order to know which position is coming up. Any optical error when the plane is distant will put the operator out of phase with his control problem, as will an undetected movement of the escapement because of vibration, receiver "swamping," electrical "noise" effects, etc.

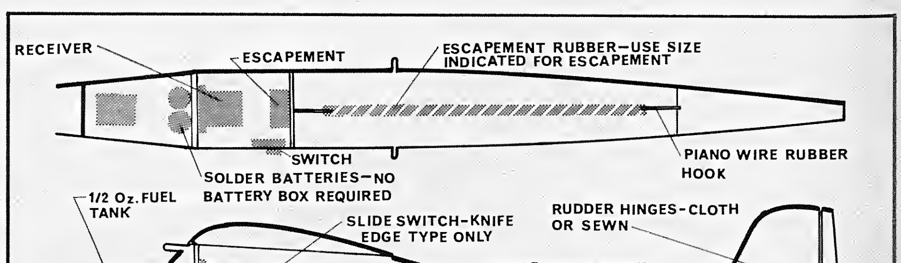
The SN escapements are popular for .01 to .02 powered planes for rudder control, and are commonly used as an auxiliary for motor control in larger single-channel machines.

Compound escapements: Many escapements are arranged to give, say, right, when a signal is sent and held; and left, when two signals are sent and the second held. Thus, one is always right, and two are always left. These are called compound escapements, although the term is technically correct only when the escapement has an electrical contact or mechanical feature to trigger another control. The trend in single-channel planes has been toward compound escapements which have this electrical contact for motor control, as well as a mechanical arrangement for holding a second control, usually elevator.

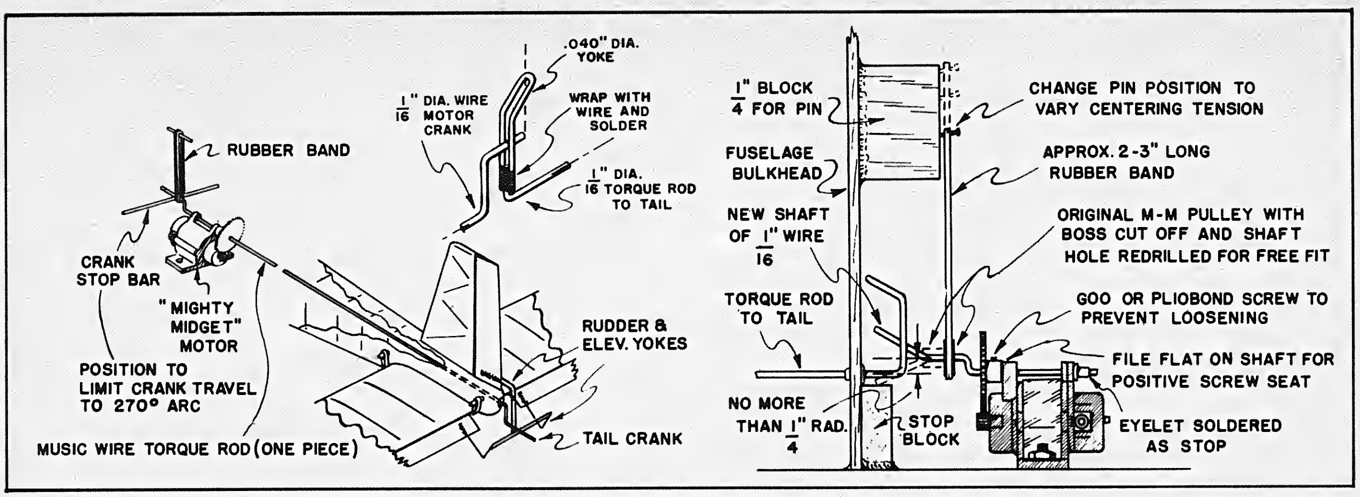
The electrical contact usually is arranged so that when the operator transmits and instantly relaxes a signal, the escapement revolves back to neutral without moving a control surface but, in doing so, causes a wipe-action contact briefly to make the electrical circuit which triggers an auxiliary escapement, servo, switching device, etc. Usual auxiliary arrangement is motor control. Sometimes the contact is arranged so that the operator can send three quick signals, holding the third, which closes the circuit to an auxiliary device. In some instances, both contacts are available —



4-7 Control yokes used in plane in Fig. 4-6. Weighted bent wire is a mass balance for the elevator. Note aerodynamic balance, forward of rudder hinge line.



4-8 Single-channel installation in a Lightning Bug.



The Simpl-Simul system: The motor-driven actuator is similar to those used for rudder-only proportional control, but in accordance with transmitted pulse variations it simultaneously operates an elevator with the rudder.

the first or "quick blip," which is passed over quickly, triggering, say, a motor control escapement, and the second contact, held upon the third signal, closing a circuit to a third actuator which moves some attitude control — elevator, for example.

More or less standard antenna installation for plane is along fuselage bottom. This one has loop of rubber at end to hook over tail skid. Can also be glued to fuselage.

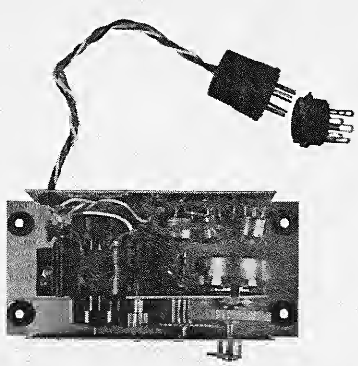
Most popular variation of the compound-type escapement is a pin stop arrangement which harmlessly "kicks up" the elevator (via a torque rod as it is passed by). Now, three signals are sent and the third is held, the escapement stopping in the position that causes this pin to lift the elevator, holding it in this inclination for as long as the signal is held. The limitation is that no other control can be applied (on single channel) at the same time — not a flight problem in a stable machine.

Cascaded escapements: Versatility is increased by "cascaded" escapements (Fig. 4-6) in any single-channel plane having installation space. Two special escapements are placed in series, each operating a primary control. Designed for this purpose is the Bonner Vari-Comp, which can be purchased singly or in pairs. The first escapement yields the usual left and right — plus a quick blip for actuating a motor control device — but the third and fourth signals feed through the first escapement into the second in such manner that the third signal, held, gives, say, up elevator, and the fourth gives down elevator. Although sequential for the third and fourth control positions, the system is easily operated.

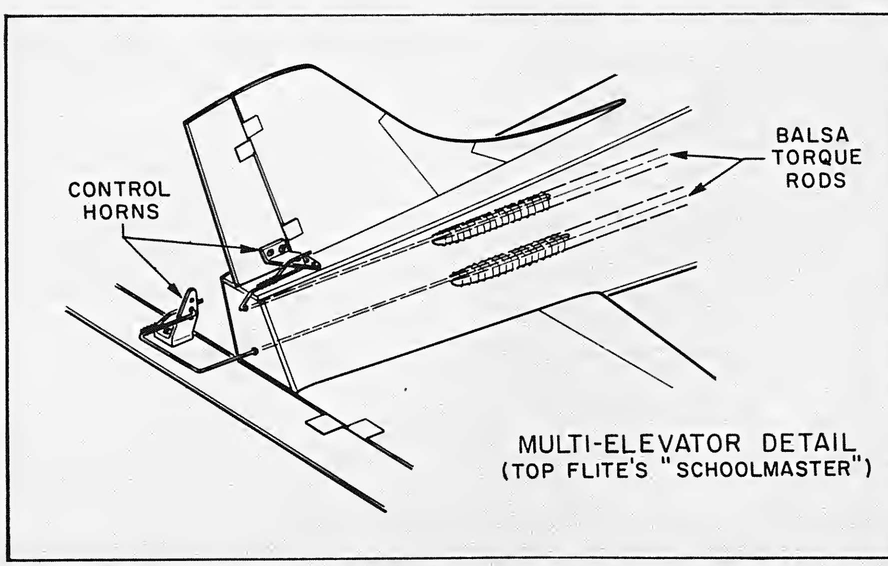
However, beyond .15 engine power there is a probability that elevator surfaces must be both statically and dynamically balanced — that is, by mass (weight forward of hinge line) and aerodynamically (area forward of hinge line). (See Fig. 4-7.) If the plane has a convex-undercambered airfoil it can do outside loops, and fly inverted with a flat-bottomed airfoil when down elevator is held.

Mechanically performing somewhat similar function is the Babcock (and others) escapement, which has special metal cams that pick up the proper control positions as the escapement is rotated and stopped where desired by the usual one, two, three signals.

The reader may wonder about the



Typical feedback servo (cover removed). It eliminates control-surface jiggling common to many proportional systems. Potentiometer in servo indicates the actuator position to receiver so that actuator continuously aligns with intelligence transmitted to receiver for the particular channel.



Attachment of pushrod for both elevator and rudder multicontrol in a small aircraft.

purpose of escapements which have a transistor circuit added. The purpose is to boost marginal actuator current coming from the relayless transistorized type of receiver (not necessary in a relay-type receiver), or to feed to the escapement an independent voltage — less subject to voltage drop — for more positive action. While there are many variations in escapements, the accompanying pictures afford an adequate perspective. To establish a framework within which systems may be evaluated, here are some popular systems concepts:

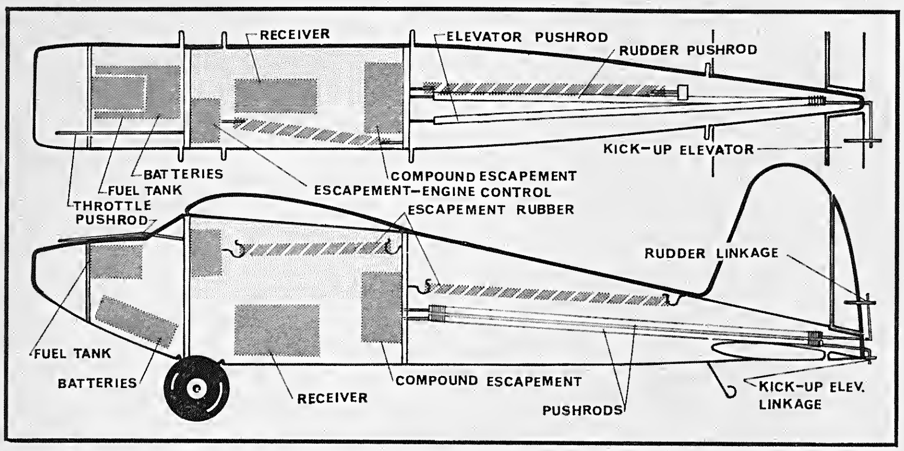
Single-channel: A steady radio frequency (such as 27,000,000 cycles per second for 27 mc) is broadcast. This "carrier" frequency can be keyed on-off. Present practice is to superimpose on a continuous or steady carrier, or RF frequency, an audio frequency of, for example, 400, 600, 800 cycles per second (cps). Thus audio is audible as a tone, being within the hearing range. For single-channel, one tone is transmitted, being keyed on-off or pulsed rapidly, depending on the actuation of the vehicle. (In multi, two or more tones can be transmitted simultaneously.) Some single-channel transmitters key tone and carrier simultaneously.

Single-channel is used with escapements, with steering machines having the same control actions as escapements, or with proportional or magnetic-type actuators specifically intended for single-channel work. (Fig. 4-8 shows a simple installation.) Auxiliary functions by electrical contacts — pulse-omission detector circuits with proportional systems — increase the versatility of single-channel operations. For boats and cars, special switching devices or steering machines string out numerous auxiliary controls if required — horns, lights, etc., for boats.

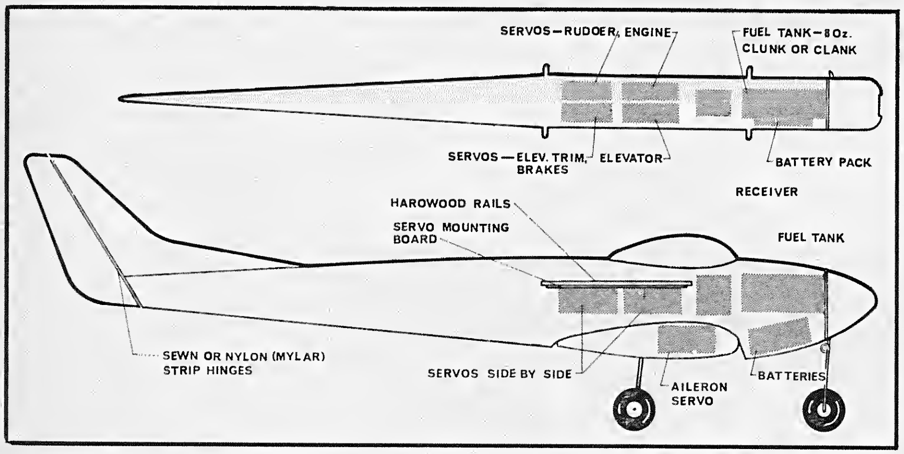
Single-channel proportional: Anything that can be flown by escapements also can be operated by "pulse" proportional. In aircraft of .049 or less power such magnetic-type actuators as the Septalette will slave to transmitted pulses. Over .049-engined planes — and for sport boats — the proportional actuator is powered by a small electric motor such as the popular Mighty Midget. Pulsed controls do cause the rudder to flop back and forth rapidly, but only the averaged position causes a corresponding response in the plane; the rudder-waggle is dampened out in water. Still another single-channel pulse variation is the feedback servo which eliminates control surface waggling — but at a greater systems cost.

With either escapements or pulse actuators there can be further interesting variations. In the Simpl-Simul system, for example, the variation of pulses by rate and length, simultaneously, causes the actuator to stop proportionately in any quadrant of its rotation, and the linkage connecting the actuator to control surfaces positions both rudder and elevator to agree with control stick movement. Naturally, all surfaces waggle furiously. Or, perhaps, a screw-jack arrangement (built into the rudder actuator) will run in and out a motor control pushrod when a no-signal condition is held momentarily. And then there are special actuators, such as the Micro 4, which give sequential controls (like a compound escapement) of both rudder and elevator, plus engine on quick blip, but using an electric-motor drive, electrically braked to stop at called-for positions.

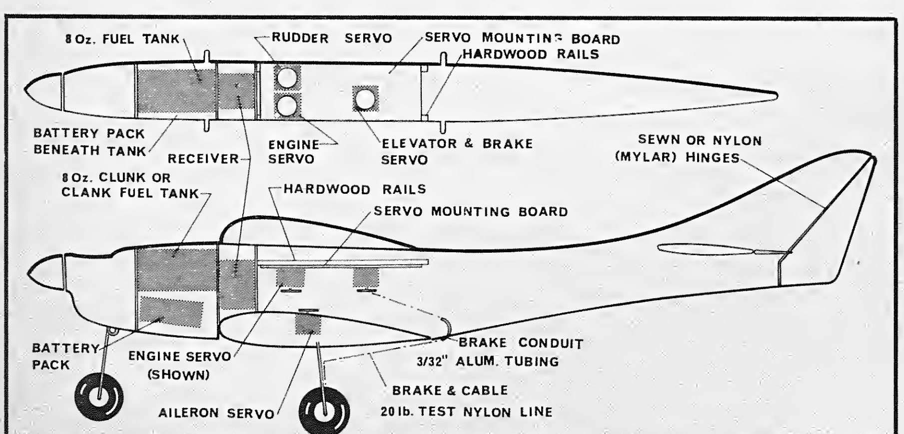
Dual-simultaneous: Two separate tones are simultaneously imposed upon the carrier, and each is appropriately pulsed to control (via certain receiver circuits) two separate servo



4-9 De Bolt Rebel.



4-10 Taurus 10-channel installation.



4-11 Quadruple proportional installation.

actuators, one for rudder and one for elevator. Proportional action is available to either surface independently of, or simultaneously with, the other. A pulse-omission detector (p.o.d.) in the receiver provides for motor control actuation. (Dual-simultaneous is considered multicontrol because of the independent availability of at least two controlling surfaces on an airplane.) If we consider contest rules — class 1, 2 and 3 — dual-simultaneous is, in an airplane, class 2, since control is about two axes. (Rules also classify any single-channel setup operating any control [such as kickup elevator] in any manner about a second axis, as class 2 and competitive to such superior systems as reeds and dual-simultaneous.)

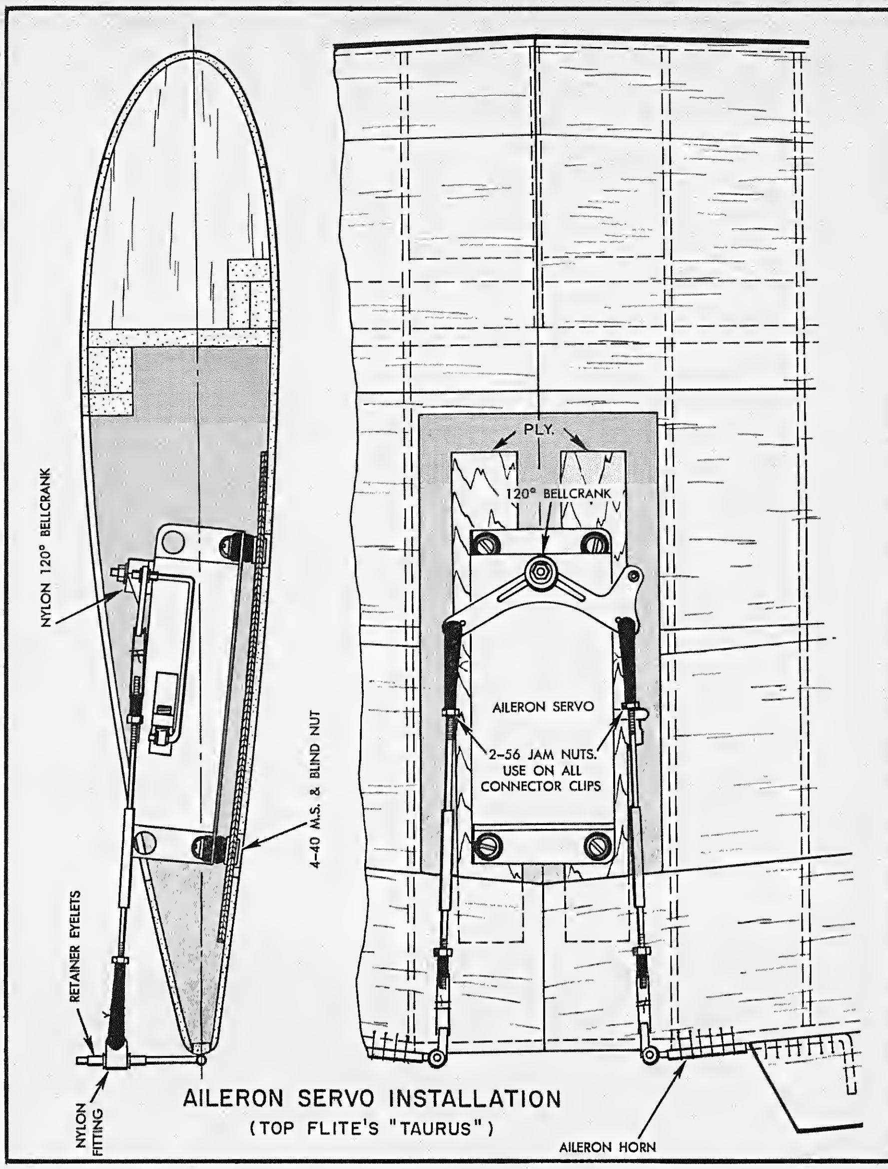
Multichannel: Again we have two basic families of control: reeds and proportional. With reeds, two channels normally are employed for each servo, actuation being by means of transmitter lever switches whose up or down (or right and left) movements cause the corresponding servo to move to the full desired control position for as long as the switch is held closed. For 6 channels or more, simultaneous action usually is available for 2 — sometimes 3 simultaneous controls with 10 and 12 channels. Fig. 4-10 shows a 10-channel layout.

A distinct tone is available for each channel. With full proportional multi, three or four (even five) independent tones are superimposed upon the RF or carrier wave, each individually varied to produce a simultaneous slaving action of an actuator to the degree of movement of one, two or more control sticks. (See Fig. 4-11.)

Not all, but most, multi proportional actuators are of the feedback servo type, which means that circuitry within the servo sends back intelligence as to its position to the receiver, where required adjustments are automatically and instantly made to agree with received signals, thus readjusting the servo position.

The distinguishing feature of the feedback servo is the freedom from wiggling of the vehicle's control surfaces or devices. In the ordinary single-channel proportional system, the actuator, flopping back and forth as it slaves to the pulsing tone of the transmitter, imparts a similar wiggling action to the airplane rudder. (In multi this wiggle is almost subdued.) The feedback servo moves only with control stick (or knob, or wheel) movement, coinciding at all times; there is no surface wiggling. An example of single-channel feedback proportional is the Marcy PRM-1 system.

Emphasis has been placed on the importance of neutralization of controls in fast vehicles. With reeds this



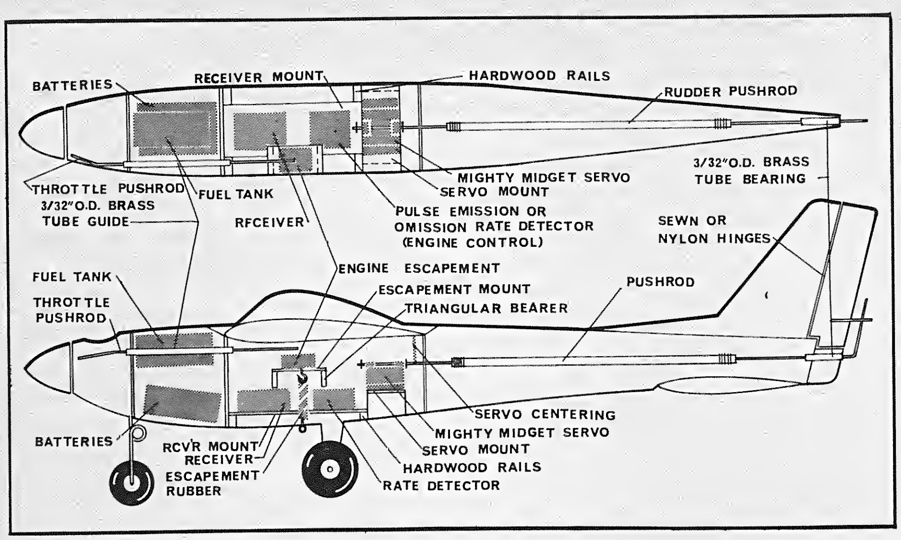
Installation of the aileron servo in a wing fitted with full-span strip ailerons.

is obtained by automatic neutral-seeking features in the servo; in proportional the control stick (or equivalent) may be spring-loaded, etc., to return to neutral when released; thus it rests in neutral unless displaced purposely. The corresponding pulsed tones, and their variations, reaching the receiver, produce a neutral on each servo — unless some trim "pot" at the transmitter has been adjusted off center, in which case the control seeks that adjusted neutral.

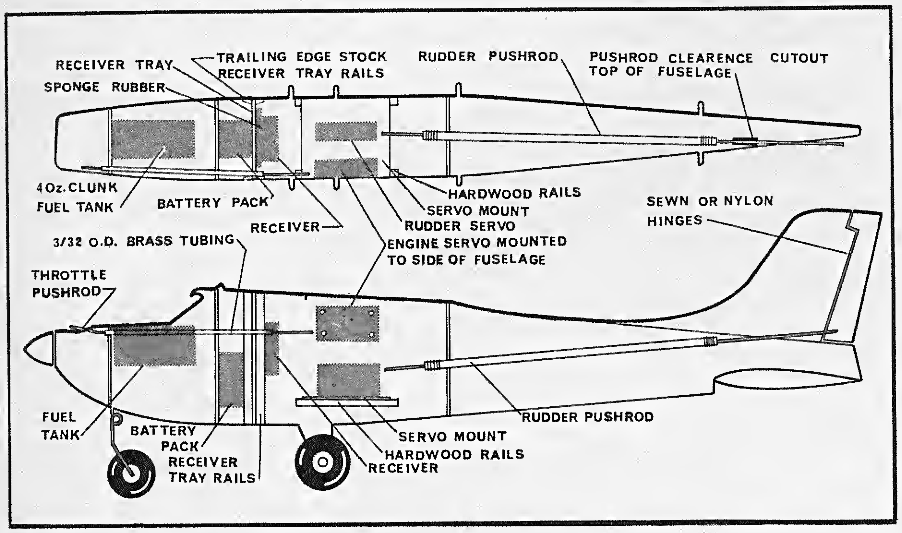
Installationwise, the multi proportional system has the same primary servos (but design differs) as the reed system but, because control is proportional, there is no need for an elevator trim servo. In the plane, ailerons and rudder are automatically trimmable by control stick movements, or can be adjusted for neutral by trim-pot facilities in the transmitter during flight. In effect, each primary control that can be so adjusted in action is the equivalent of an additional servo which would have to be added — but never is — to the reed system for even roughly comparable results. The proportional vehicle which has a tendency to deviate from straight paths when in neutral can be held to position by slight off-center holding of the control stick(s), or trim pots can be adjusted. With reeds — excepting the elevator trim servo — continued flight path adjustments have to be made under such conditions, all being noticeable and bothersome. (Fig. 4-12 shows a single-channel installation.)

How many channels?: At the two extremes we have the popular single-channel and 12-channel and multi-proportional rigs, but between these most simple and most complex systems, a number of natural categories have developed. The most useful of these are the four- and six-channel reed systems.

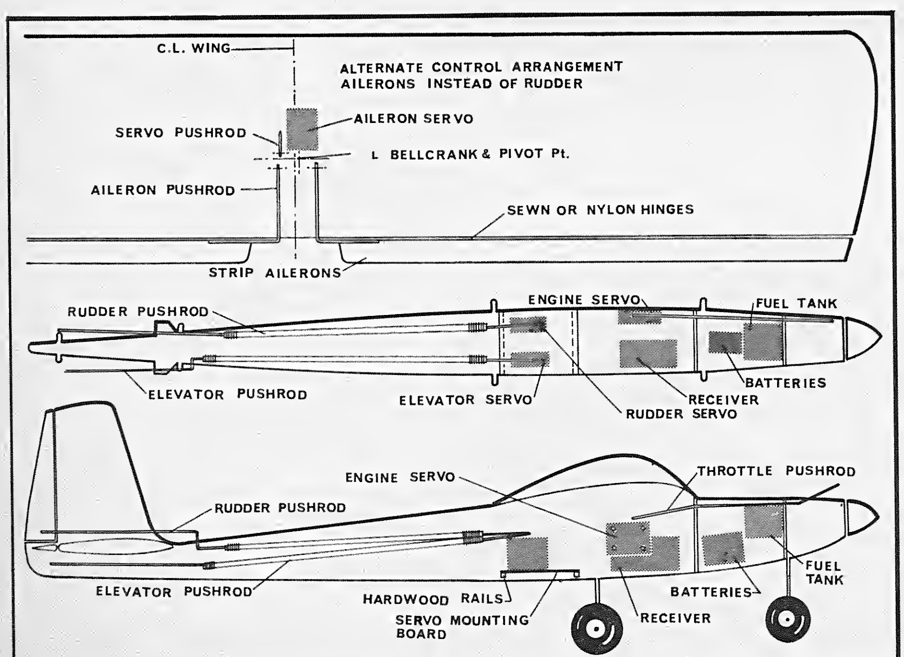
A typical four-channel system (Fig. 4-13) involves the use of two channels for rudder — one left, one right —



4-12 **Rudder Bird single-channel pulse installation.**



4-13 **Tri-Squire four-channel installation.**



4-14 **Falcon 56 six-channel installation.**

and two for positionable engine servo control. The transmitter, of course, can have more than four channels. Such a model won the rudder-only event at the 1963 Nationals.

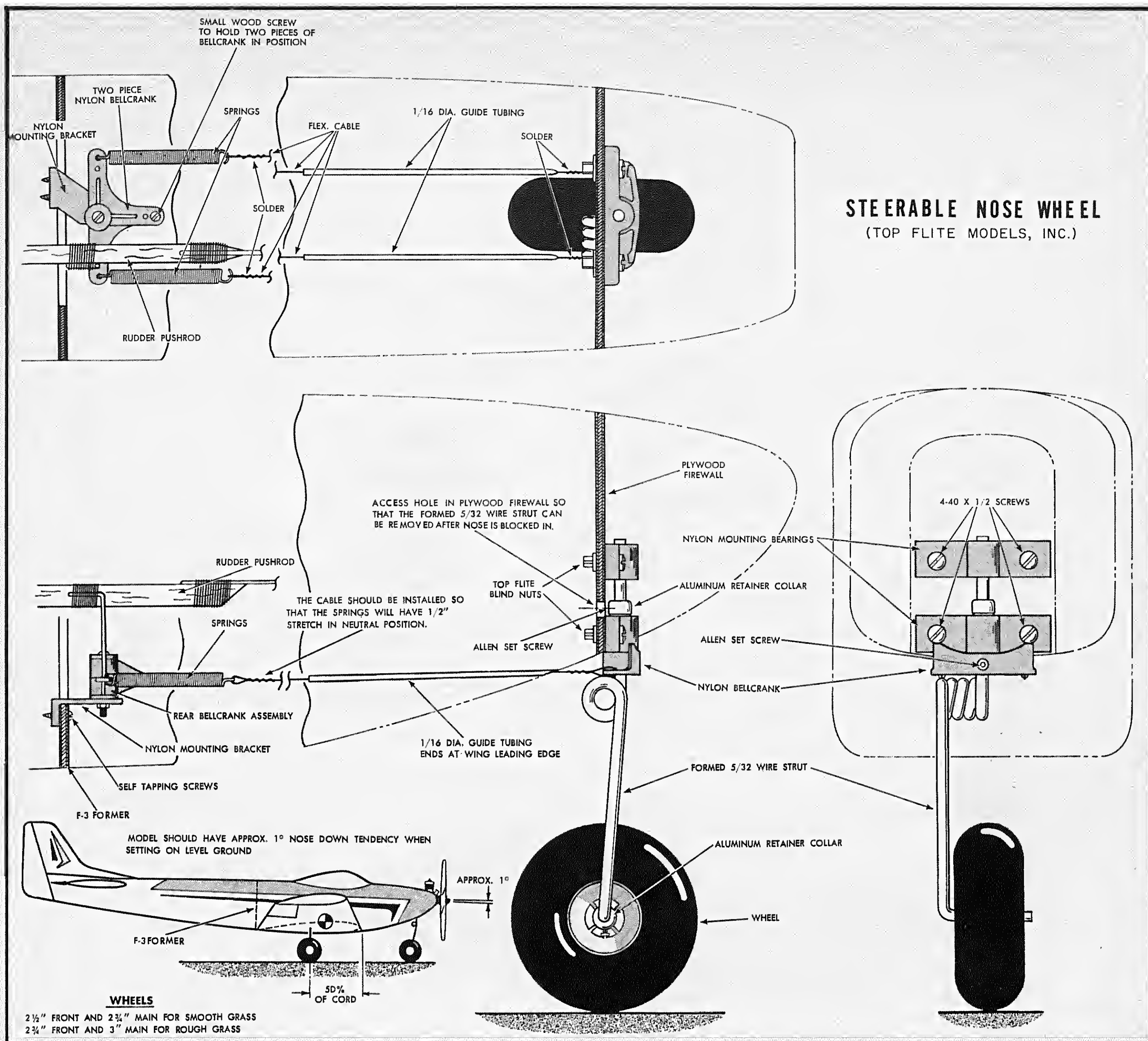
More popular — because it approximates "full house" controls at lower cost — is the six-channel radio which gives two channels for rudder and two for engine (as with four channels), but provides two more channels for elevator. If ailerons are substituted for rudder (Fig. 4-14), maneuverability is greatly enhanced — rolls, for example — and the pilot's ability to remove the airplane from dangerous overbanked diving attitudes is increased.

Steering and braking systems: Virtually every multi flier wants steering ability for ground maneuvering and for responsive directional takeoff runs. If he is a contest flier he requires braking as well. In fact, any nose-wheel ship can be given steering ability, even on rudder-only planes which have sufficient actuator power (such as a rudder servo). Indeed, steering is so often considered an integral part of the control system — braking somewhat less so, but frequently a factor — that illustrations are included in this chapter to show such arrangements.

Fig. 4-15 illustrates the Top Flite system for a steerable nose strut. There are a number of other systems, basically similar in principle but differing in details; and at least several other commercial nose-wheel items are available at the hobby shop.

Figs. 4-16 and 4-17 show details of a braking system for a tricycle landing gear. The significant feature of this setup is that ordinary wheels are used. Wheels which have integral brake drums can be purchased, but their actuation would be roughly the same — that is, a down movement of the elevator trim servo, as soon as the craft touches down, exerts tension on the brake lines.

The reader should not feel discouraged by this sudden exposure to what essentially is the whole basic concept of radio control in all its popular forms. Having established an impression of the varied nature of the techniques, depending upon requirements and conditions, we easily can clarify matters by discussing in turn each of the popular, commonly accepted combinations of vehicles and control systems. In subsequent chapters we shall confine discussion to categories of planes and boats, the hobby's most popular divisions, then deal specifically with detailed installations for both types of models. Finally, a special section compiles working examples of outstanding vehicles of other kinds, from clamshell derrick to army tank.



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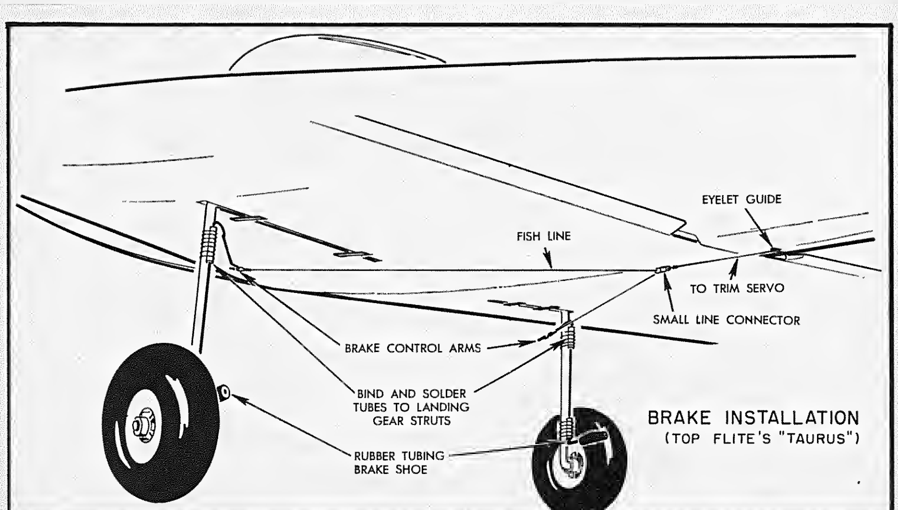
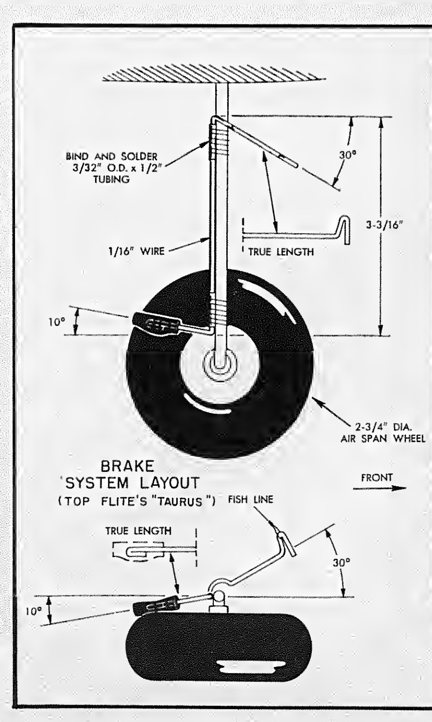




4-16 Braking system used on planes with tricycle landing gear: Brakes are applied when the elevator trim servo is run to down position, which pulls on line at right. Many brake systems exist, including wheels with integral brakes.

4-17 Right: Additional details for braking system shown in Fig. 4-16. Brakes are necessary on competition multicontrol planes for point-yielding ground maneuvers.

A scale multicontrol Fairchild trainer made from a kit.

5: TYPES OF AIRPLANES

THE interplay of design factors in a radio-control plane is widely recognized. It is difficult for a beginner to make an aircraft without benefit of a kit's proven design. The experienced modeler usually concedes a kit's advantages.

In talking about kits we will note many points which apply to all projects, regardless of the origin of the design, plans or materials. Kits incorporate arrangements which properly and conveniently locate batteries, receiver, actuators and linkages, providing correct balance of the completed machine and accessibility for servicing and maintenance.

Certain factors influence choice of subject. Most multicontrol aircraft are large (5- to 6-foot span), and require costly equipment. Those having four or six channels of control fall midway between the extremes (about 4½ feet) afforded by 10- and 12-channel and multi proportional craft and the smallest planes. Single-channel designs are small (16″ to 26″ spans) to medium (3-foot to 4½-foot) in size, relatively inexpensive and easier to make. If you are not experienced, the simplest and most economical systems are recommended.

Some people prefer cabin-type designs, others low wings, midwings or even true-scale craft. Cabin-type machines usually are inherently stable — important for the beginner — but an open question where multi is concerned. Multicontrol aerobatic designs favor a near neutral stability which permits rapid, smooth and forceful maneuvers. This is why low wings and shoulder wings stand out in multi. The shoulder wing usually, but not always, is more "hands off" stable than the low wing, which does require a deft pilot because it has to be "flown" most of the time. Many cannot remain airborne without more or less constant controlling. In real aircraft these stunt machines would be the fast, tricky fighters — whereas the simple, rudder-only cabin jobs are the Cubs and Cessnas.

R/C airplanes can be classified in many ways: by design, flying, structure, power, radio, controls, and by combinations of these things.

Basic types: Most common configurations are cabin, shoulder wing and low wing. Occasional special types include biplanes, seaplanes, and flying boats, deltas.

The cabin model: Generally credited with greater inherent stability and free flight ability, this category is preferred by most beginners, and is popular for single-channel — mostly rudder-only (usually plus engine control) — and sport or beginner multi, with four to six channels.

The shoulder wing: Usable for single-channel, but not so widely so as the cabin types, the shoulder wing will have marginal to adequate stability in this class. It also is one of the two principal variations of popular multi stunt ships, exhibiting better natural trimming tendencies than a cabin type (tends to fly flat with less climb and zoom tendencies) and, usually, is less

Ed Kazmirski with his multichannel Taurus, winner of the World Championships in 1962.

The Miss America, a small .049-powered cabin model designed by author William Winter.

The author test-glides a new .19-powered cabin model.

tricky than a low-wing multi. In common with most cabin types, its wing detaches readily in hard contact with the ground (if front dowels, etc., for rubber bands face forward), whereas the low wing traps its wing beneath the fuselage upon diving in.

The low wing: A basic multi type. It is less vulnerable to cross winds on takeoffs and landing, flies "flatter" or "gets on the step" better than other types as a rule — but only as a rule, since some shoulder wings are acceptable in this respect. Low wings usually force location of main wheels under the wing, mounted to the wing frame, whereas cabin and shoulder-wing types allow knockoff gear attachment to the fuselage.

Biplanes: Seldom used for contest work and more time-consuming to build, biplanes are a special, or scale, interest, with emphasis on sport flying. Other things being equal the biplane is more compact than the equivalent monoplane. As a rule of thumb, the total biplane wing area can be figured as five fourths that of the monoplane. Among the structural problems are knockoff wings (top wing is usually rubber-banded on steel-wire struts and cradle) and, in multi, the aileron location and linkage.

Seaplanes: These are of two types: flying boats and float planes. Floats (pontoons) can be added to practically any land type. Flying boats, oddly enough, show tremendous variations in size (flying "field" size is unlimited), ranging from .01 power up to 15-foot monsters with .60-cu.-inch engines, and are always flown for sport. Strap-on landing gears attach readily to hull bottoms. Flying boats can alight upon grass — sometimes take off — without damage.

Performance types: Classifying planes by the kind of flying they do, we have true contest models, sport jobs and scale aircraft, although all can be flown for both purposes. The great majority of single-channel designs are sport-flown, but most (of 4-foot or more span) are suited for both purposes, but with bigger engine for competition. Since contest winning multi designs are so widely kitted, they are universally used for sport as well.

Size and power: If we classify planes by wing spread and size of engine, we find roughly these combinations in single channel:

20″-30″ span .... .01 engine
28″-36″ span .... .02 engine
36″-44″ span .... .049 engine
40″-48″ span .... .09 engine
50″-56″ span .... .15 engine
56″-66″ span .... .19 engine

(These power figures are conservative for sport.)

In multi we have these combinations:

56″-60″ span .... .15-.45 engine
60″-72″ span .... .36-.60 engine

These figures are approximate because of differences in installed (hence gross) weight, engine size and quality, etc. In the smaller sizes full-house multi weighs down the plane sufficiently to make it tricky to fly. With more elaborate installations, a .35 to .45 engine would be better for a 60″ plane than a .15, or .25, etc.

In single-channel the tendency is to use one size of aircraft with a wide variety of engine displacements, such as a lightly built 50″ craft with a .09 for training or sport, or with a .15 — even a .19 — for competition. Also, single-channel proportional often means a greater installed weight due to larger-capacity batteries for higher actuator drain; but proportional control is so superior to escapements that higher power can be employed — a .19 powered ship may have a .35 engine.

With high power, the single-channel ship should have three-position, rather than two-position, motor control:

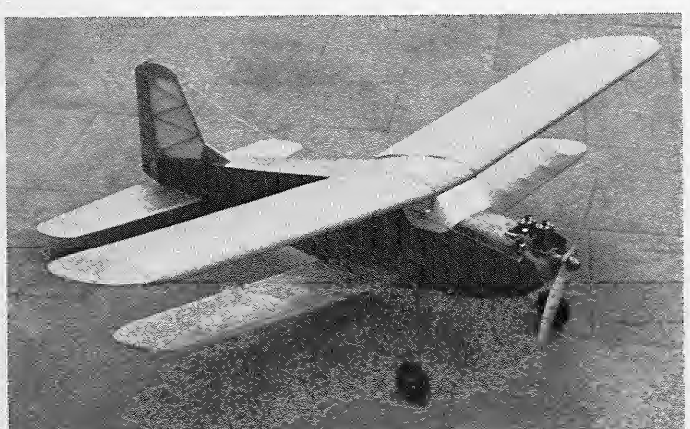
Typical multichannel types lined up for takeoff. Left to right: Smog high-wing, original biplane, Cosmic Wind low-wing, scale Mustang.

high, cruise, and low. Travel over the ground, against a wind, requires cruise throttle. High would be used for short, fast climbs for stunts; low, for power approaches. Motor control must be dependable with such a setup because the typical high-wing plane for this event becomes unmanageable if stuck on high motor. (The feedback servo system permits positionable engine control.)

The 56″-60″ bracket for multi covers much ground. Here we find the so-called trainers — Falcon Sr., Tauri, Jenny, etc. — which can fly on rudder plus throttle, or with elevators added. Many people add ailerons as well — though the Jenny does include strip ailerons. At the higher end of the scale — that is, 60″-72″ — even a 10- or 12-channel (or multi proportional) rig can be fitted.

Let's relate single-channel and multicontrol systems. In single-channel for .01 to .02 engines, rudder-only is adequate. For .049's, rudder-only usually is satisfactory, but motor control is a reasonable addition. The .049 is the natural dividing line in single-channel because this size of plane and engine allows installation of additional actuators — plus motor control.

A limited form of elevator control which can be used sensibly for any rudder-only craft, most ideally for the .049 engine and under, is the "kick-



Biplanes are often built for sport flying. This one has an in-line two-cylinder engine.

Ready-to-fly small German single-channel model made of styrofoam with wood inserts in high-stress points.

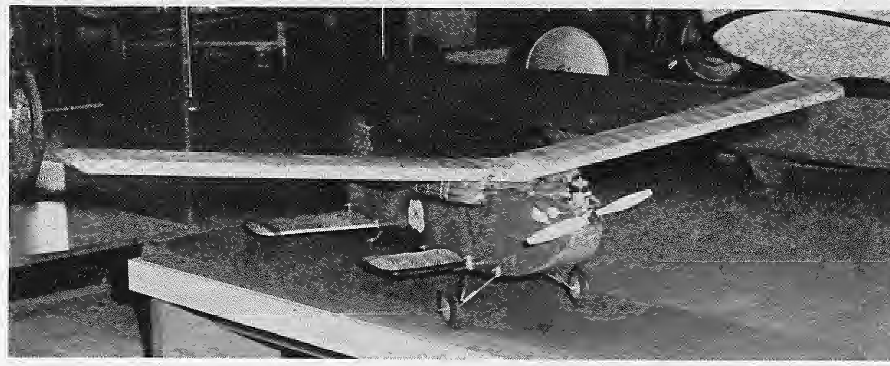
up" feature described in the preceding chapter. This gives "flared-out" landings and clean loops. Several makes of escapements incorporate the "quick-blip" engine control feature, as well as kickup elevator.

For the smallest planes, compact, lightweight escapements should be selected, such as the Citizen-Ship and Bonner SN types. For the .049 and up, a sturdy, compound type of escapement should be employed.

The inclusion of multiple controls produces several distinct combinations of planes, each of which requires certain individual characteristics — in general, the more the available control surfaces, and the more the piloting skill, the less the inherent stability that is required of the machine. Excessive stability inhibits aerobatics, and, in fact, a full-stunt ship possessing great inherent stability with "full house" controls can become exceedingly wild in the air, as the automatic corrective movements of the plane actually compound trouble. But when the use of fewer channels eliminates some control—usually aileron—greater inherent stability must be designed into the craft.

Four channels: The optimum arrangement is two channels for rudder — one left and one right — and two for a positionable motor control via a second servo. The plane must possess sufficient stability to recover to normal flight after a rudder application, and to free flight when no controls are given. It is flown in the same manner as a rudder-only model, but more precise pilotage is possible. Contest-minded folk can use a big engine, pulling as much power as is required for any maneuver or flight attitude. All cabin types of 50″ and up in span — 56″ is about ideal — are well suited to four-channel operation; and some shoulder wings are eligible, provided they have sufficient dihedral to recover by themselves from steep turns.

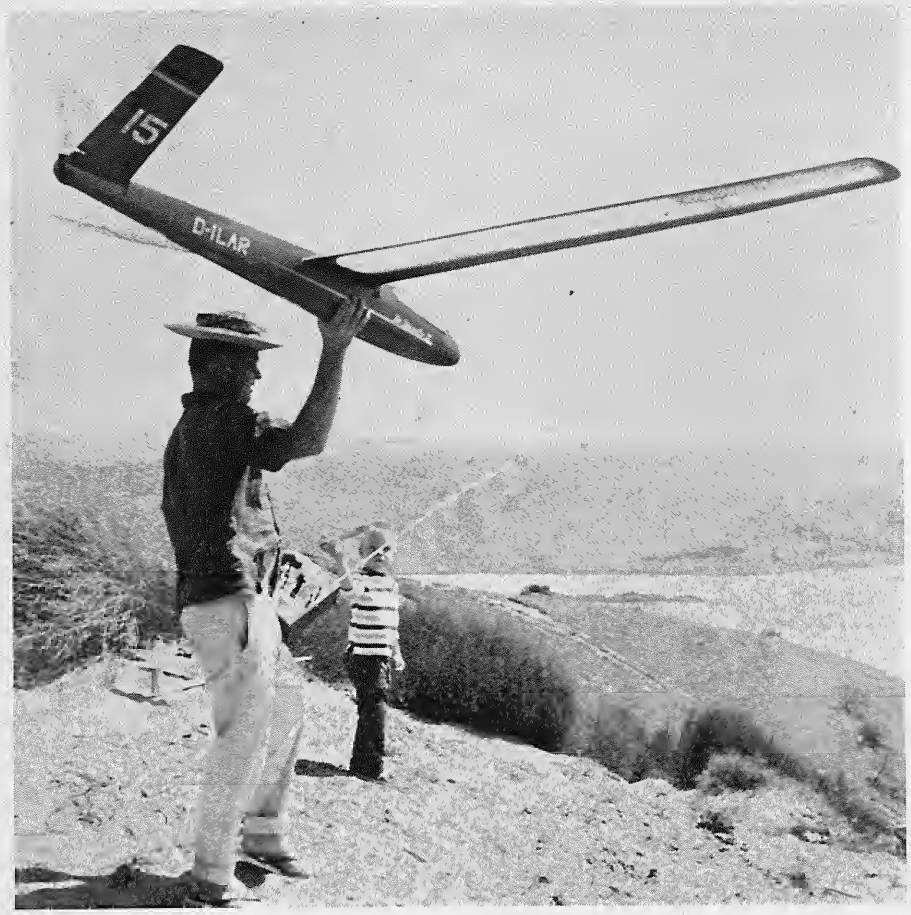
Six channels: Here we have new options. First, the setup just described can be repeated — as it can be with any multi receiver leaving some channels unused — but quite likely you would wish to add elevator control. A flat-bottomed wing suffices on most cabin configurations, but the convex undercambered type (common to multi) affords smoother maneuvers and greater stunting capability — such as outside loops. Since aileron control is lacking, rudder action must be adequate to reliably control the ship in all turn-and-bank situations; and this, in turn, necessitates more dihe-



Ken Willard's former single-channel world duration model (approximately 5 hours 29 minutes) upon its presentation to the Smithsonian Institution.

Frank Ehling congratulates Maynard Hill after world altitude record flight of more than 13,000 feet using multi proportional control with feedback servos.

Author rubber-bands wing onto rudder-only plane. Wing knocks loose in a crackup.



Jim Drever prepares to launch his multicontrol 9-foot semiscale glider for a slope soaring flight. It does all stunts.

dral than might be desirable with a "full house" multi. For contest work the rudder action should be powerful enough to perform rolls.

There is, however, one extremely promising modification which greatly enhances aerobatics with six channels: this is the installation of ailerons rather than rudder. For example, the Falcon, when equipped with 1"-wide full-span strip-type ailerons, will do most of the full-house maneuvers, usually excepting spins, but with limited ground handling, since in this case there is no rudder servo in the fuselage. Steerable nose wheels ordinarily are linked to a rudder servo. Six channels figure in a marked variety of sport craft, including such huge flying boats as the Custom Privateer.

Eight channels: These radios can be employed in either of the above categories, as well as for full-house installations, the principal difference being the availability of rudder and ailerons, but still lacking trim elevator. Not all sixes provide for simultaneous control; the eights have simultaneous. However, 10's and 12's — and multi proportional — have outmoded the eights.

Ten and 12 channels: For full-stunt machines, or stuntable scale models (like the Mustang and Spitfire), these systems are ideal in low-wing or shoulder-wing types as previously described, of between 5- and 6-foot span. A few cabin models fall into this category — Mighty Mombo, Smog Hog — though the cabin types cannot match, say, the low-wing Taurus in competition. The choice of plane type depends on how much inherent stability you require and the relationship of flying experience to the sensitivity and speed of the aircraft. For example, an Orion is harder to handle than its bigger sistership, the Taurus. Twelve channels permit such auxiliary controls as wing flaps and retractable landing gears.

Multi proportional: Superficially the proportional airplane and its servo installation resemble the reed-type configuration but, as a rule, there are important differences in handling and, hence, control system requirements. The Taurus is an excellent reed-receiver machine which smooths out the jerkiness in maneuvers so annoying in very responsive machines. Yet, without modifications, it is not an ideal proportional plane. The proportional craft frequently requires changes in the area and movement of various control surfaces, sometimes even in proportions.

Installationwise, the proportional ship has the same primary actuators; yet, because control is proportional, there is no need for an elevator trim servo. Ailerons and rudder also are trimmable, in a sense, because of proportional action. These controls can be adjusted in flight, which means that reed systems would require still additional servos for approximately similar effects.

Two wheels or three? Two wheels are cheaper, lighter, and more easily installed than three. In a sport model it matters little which type of landing gear is used, though, in multi, three wheels usually have an advantage. The proper positioning of the two-wheel gear is quite critical — too far forward and takeoffs tend to groundloop; too far back and the ship noses over upon landing. For contest work the tricycle landing gear is almost a necessity. Two-wheel low wings tend to nose over.

It is difficult to make touch-and-go landings with two wheels. The "trike"

An endurance record attempt with a four-channel model. The ship, followed by car carrying the pilot, is taking off carrying 18 hours' fuel for a .15 diesel. Engine failure terminated the flight at 2 hours 30 minutes.

gear eliminates fussing with elevator control during the takeoff run, especially in grass, and reduces, if not eliminates, rudder corrective action required by "swing" due to engine torque — usually most evident when the tail rises off the runway. The trike-gear ship can be flown onto the ground at good speed and a constant angle, thus minimizing control corrections during the approach and rapidly changing evaluations of attitudes.

What about brakes? For sport flying few people bother with brakes, but brakes are essential for contest work. They permit realistic ground handling, such as taxiing to takeoff, stopping, then gunning the engine for the takeoff run. With two-wheel gear, braking is achieved by having slight drag on the main wheels, or severe drag on the tail wheel; or by a stop arm arrangement which engages the tail wheel tire when up elevator is given. For the trike gear numerous original systems exist for braking, but commercial wheel brakes are available. The trike gear allows severe braking after landing, because the ship will not nose over; also, there is a choice of braking the nose wheel or the two main wheels. Brakes are applied by holding down elevator trim, with a monofilament line running from the servo pushrod, through a metal tube conduit, down the landing gear struts to the brake actuation arms. After landing and braking, the trike-gear ship, in a nose-down, no-lift attitude, seldom bounces or becomes airborne again.

An Italian multicontrol model pulls up to make another landing attempt at the World Championships.

Joe Martin's twin-engined Air Force turboprop XB-47-D with two .45 engines and 10-channel radio.

6: BUILDING THE AIRPLANE

WHEN building an original design, working from magazine plans, you can hand-pick the wood. If a kit, you depend on the manufacturer. Although manufacturers control the quality of wood, it is inevitable in a kit that an occasional piece may be too hard or too soft for its purpose, or be otherwise deficient. The selection and handling of balsa plays a large part in the success of any project.

For example, one of the author's designs for a magazine weighed 6 pounds; yet, when built from the published plans, individual models weighed from 5½ to 8 pounds! The average modeler frequently builds from 1 to 2 pounds heavier in a multi-control craft than did its designer. Where does the excess weight come from? Hard and heavy wood where not required, superfluous glue, layers of paint, and so on.

Selection of balsa: Excepting such high-stress points as the firewall or engine-mounting bulkhead, engine bearers, landing gear attachment bulkheads and plates, etc., balsa is almost universally used in the R/C plane. Because it grows at the rate of 6 feet a year, the balsa log varies in density — sometimes within a few inches, so that one edge of a sheet may be much harder than the other edge. Even acceptable modelbuilding grades can vary between 100 and 200 per cent in hardness. This is actually an advantage in that soft, medium, and hard pieces can be selected according to intended use. Depending on the cut from the log, grain characteristics also vary radically. Some wood will be quite pliable along the grain—useful for sheeted leading-edge sections on wings, rounded-off superstructure on a fuselage, etc. — but other wood will be so rigid along the grain that any attempt to bend it splits it end to end. Such grain is good for ribs (when light), trailing edges, spars, etc., when hard.

Wood should be selected for straightness, grain, and hardness. (See chapter 3, Materials.) Although only experience enables an ideal selection, the beginner can readily detect the difference between soft and hard, and can realize that mushy wing spars will result in wing breakage. There are so many good kits these days that much can be learned about wood just from observing its usage while assembling the model.

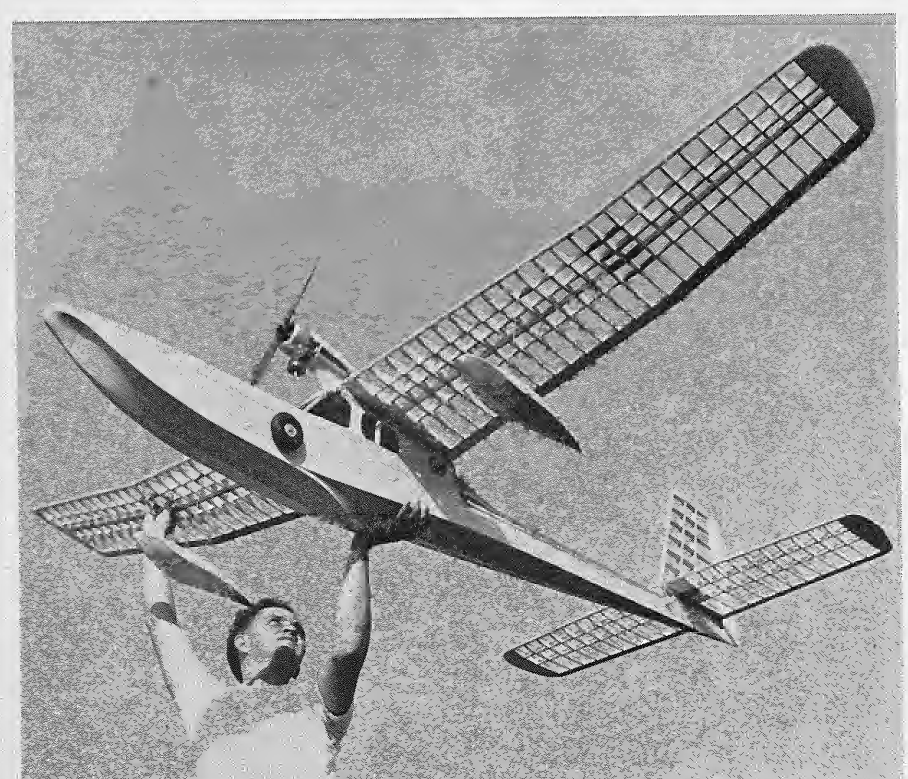
Fuselage sides should be light but not mushy, calling for a medium-soft to medium density and a stiff, not pliable, grain. Spars should be rock-hard, as should solid trailing edges. Wing sheeting should be medium-soft to medium, pliable. Trailing-edge sheeting should be medium to hard, but very stiff-grained, because covering can curl it one way and bow it the other (lengthwise). A sheet-balsa tail — common in small models — should be medium-soft to soft, but stiff-grained. Such tails, by the way, are protected by several coats of clear dope which should be plasticized (to prevent dope from bending the wood) by adding 8 or 10 drops of castor oil to about 2 ounces of dope. All shaping blocks must be soft and light. Bulkheads, excepting those which support some load-imposing part, should be soft.

Poor placement of balsa grades in the airplane drastically affects performance, the tendency being to build a tail-heavy machine. If hard balsa is used for movable elevators, for the rudder and fin, for bulkheads aft of the trailing edge, even for the fuselage sides, your model almost certainly will balance to rearward of the designated center of gravity. So, while wood must be selected for appropriate strengths — by weight and grain — it cannot afterwards be carelessly used. A word of warning is enough. Wood selection is only common sense.

Inspection of kit: Examine carefully for doubtful wood. Watch for such things as spar or edge material that is heavy and hard for one wing panel or fuselage side, and soft and light for the other. This inspection has other purposes. Wood pieces should be identified for placement in the project, to avoid cutting wrong pieces. Shortages should not develop before the plane is finished, as happens when crosspieces are cut from longer pieces meant for spars, etc.

This matching of material against the plans is a valuable briefing on procedures. It is necessary to know the sequence of assembly. Even experts sometimes find one step taken too soon has blocked a later step.

The myriad pieces of wood that comprise an airframe can be assembled into untold combinations, making



Don McGovern and a huge flying boat. Note the multispar construction of wing and tail. Hull is the NASA planing type.

it impossible to describe all specific arrangements that might be encountered. We can detail basic methods, highlighting good practice.

Fuselage: Accurate alignment is attainable by constant checking as work progresses. Several common errors occur in assembling fuselage sides to crosspieces or bulkheads. One is twist — tail surfaces out of line with the wing. Even when the flying surfaces are lined up (by shimming) during final assembly, the crooked construction is obvious. Twist causes the vertical tail to lean, imparting a tendency to turn.

Less obvious, but equally important and occurring frequently, is an assymmetrical bend in the fuselage — that is, when the sides are joined at the stern post, or pulled in at a nose bulkhead, the stern post (or nose) is not on the center line of the airplane. This throws the stabilizer platform out of line and angles the fin toward one side like a built-in rudder. To err is easy when one fuselage side is thinner or weaker than the other. Careless application of the sides to the key bulkheads when assembly is started creates subsequent alignment problems which cannot be eliminated. Simple checks prevent these difficulties.

Most fuselages are boxlike, with flat sides, top and bottom. Such a fuselage can be rested on any of its flat surfaces, as convenient, for checking alignment during construction. Some are so designed that the fuselage bottom, from the front of the cabin to the very tail, can rest flat on the bench. If the bottom is not flat, the top of the fuselage (in cabin types) usually is, at least where the wing is located.

Suppose that sheet balsa sides have been attached to the two main fuselage bulkheads. Now stand the body on the top view of the plan. If the sides do not make a 90-degree angle with the bulkheads (top view), the bulkheads will not line up with the plan, but will slant toward front or rear. The bottom, or top, edges of the bulkheads can be pinned temporarily to the bench. Unless corrected now, an accurate fuselage cannot be completed. It is a simple matter to align the sides before the cement has set.

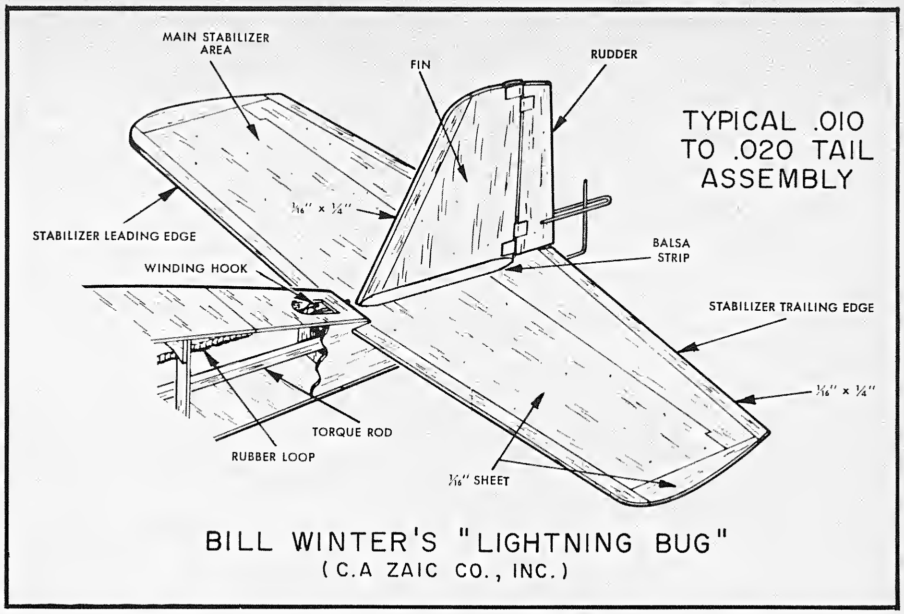
The fuselage sides should be vertical to the bench. Check with a draftsman's triangle or convenient right-angled object. If the sides are not vertical to the bench, the fuselage will be out of line. If necessary, remove the holding pins while the cement is wet and reattach the sides to the key bulkheads. (The benchtop can be used as a convenient gauge in many ways.)

The midfuselage area — the section through the cabin — usually can be aligned and allowed to dry before joining the sides at the rear. An old battery or other heavy object can be placed on top of the fuselage to press it uniformly against the benchtop, preventing accidental movement while the cement sets. A helpful trick is to attach one piece of bottom sheeting across the fuselage adjacent to one of the main bulkheads, thus further locking the work against accidental movement; when the sides are pulled in, either front or rear, the cabin section cannot shift.

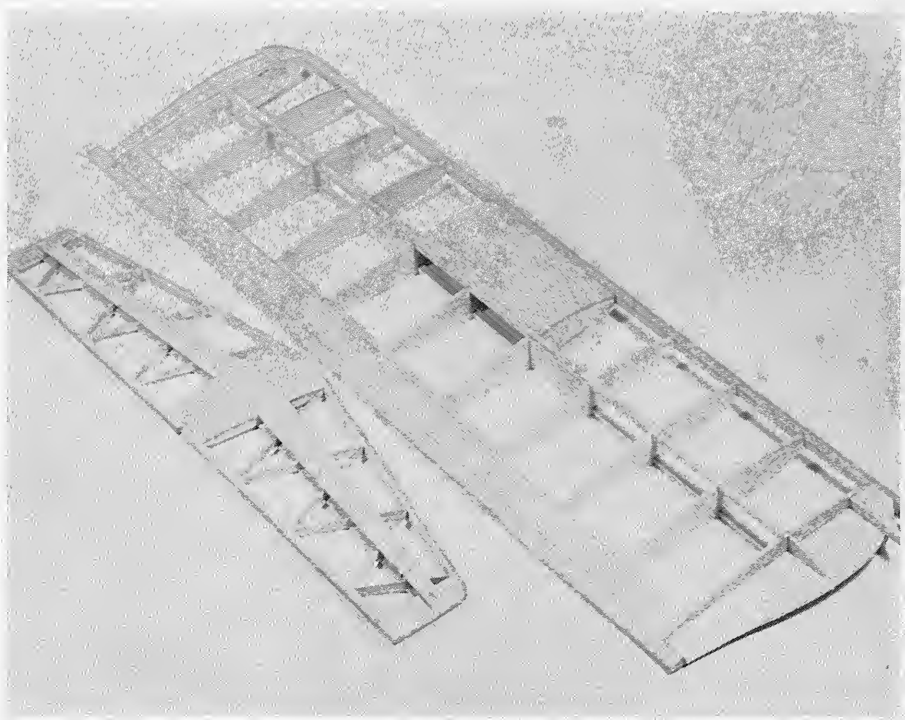
It is extremely important that the sides join on the center line. Place the fuselage on the top view while you make trial fits. If the rear is off to the right or left of center, adjust the joint before the glue dries. Or lay the fuselage on its flat side at the cabin, then measure up on half the fuselage width from the benchtop at the stern post. (Fig. 6-1.)

Before the sides are joined to the main bulkheads, it is advisable to rule in lightly with soft pencil the exact locations of all uprights. (Fig. 6-2 shows the typical cabin model fuselage.)

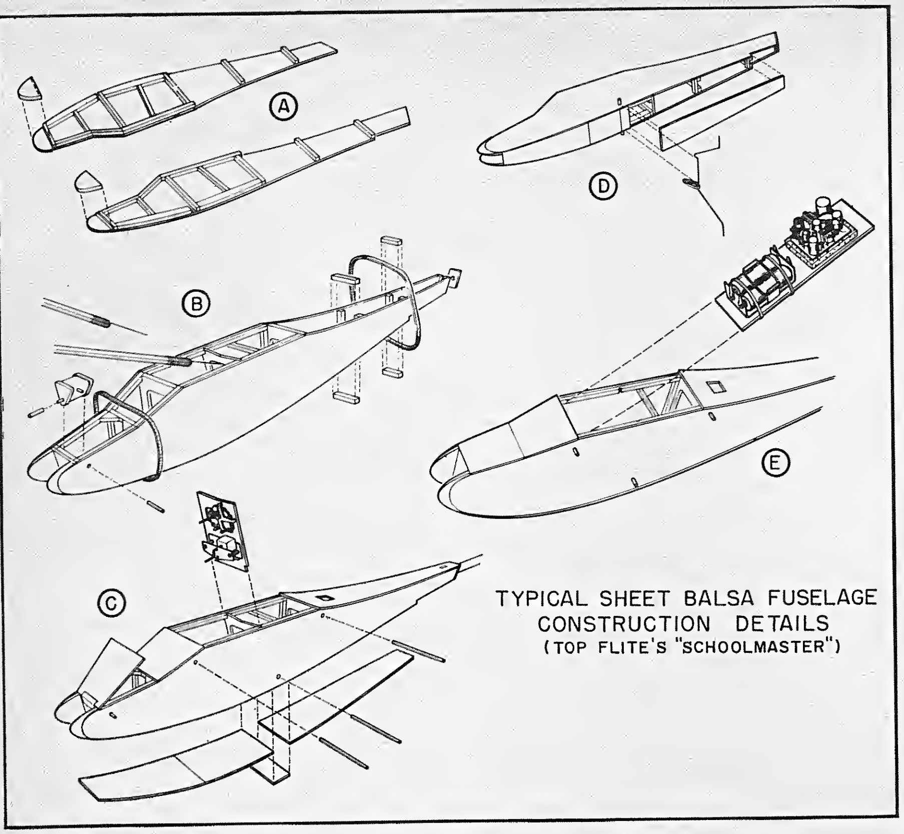
Also, if the sequence permits, it may be feasible to attach all doublers



Sheet balsa is good for tail surfaces on small models. The edging on the stabilizer is warp-resistant.



Large stabilizer (before sanding) is for a 7-foot camera plane; small stabilizer, typical of multi stunt planes, is from a Tauri. The diagonal crosspieces resist warping.



Five stages in the assembly of a typical medium-sized kit.

at this stage, using contact cement, rather than insert them later with regular cement.

Other considerations: There is a relationship between construction and radio installations which concerns us now. First, there is the problem of access hatches, defined by the type of fuel tank and the location of the batteries. Secondly, there is the business of arranging actuators, pushrods, etc., before construction is buttoned up. Normally, all these items can be installed after the basic assembly is finished, but frequently it is difficult to insert such items if working space is cramped. A precheck can be made by placing actual-length parts (pushrods, etc.) over the side view of the plan. This indicates how access can be had.

In the typical multi stunt model the nose section is open at the top, providing access for the battery pack and the plastic bottle "clunk" tank (which has a weighted surgical rubber fuel-line pickup inside). (Fig. 6-3.) A snug-fitting hatch covers the area and keeps out raw fuel and exhaust. Although adequately strong, a beginner who will abuse a model is better off with a still stronger enclosed nose. Here, a metal "clank" tank (which has a metal, weighted swivel pickup inside) is buried, and the top of the nose is permanently blocked in. (Fig. 6-4.) If rechargeable batteries are employed they too can be buried in the nose to maintain balancing requirements. However, in such installations the preferred method is to suitably reinforce the front cabin bulkhead, which usually is plywood or faced with plywood, so that an access hole can be made in the bulkhead. This permits inserting the usual foam-rubber-wrapped battery pack through the hole and allows its removal whenever necessary. (Fig. 6-5.)

In nonstuntable models (mainly those which do not fly inverted) the tank need not be either clunk or clank types, though they can be used. Here, a metal rectangular tank is preferred. The clunk tank must be accessible because, in time, the surgical rubber tube deteriorates. The clank type can be buried, as would be the more usual single-channel types of tanks—wedges, rectangular tanks, etc. (Fig. 6-6.)

These conditions are mentioned because the builder will find that a kit which shows one particular arrangement may require modifications before assembly passes the point of no return. Give particular attention to the motor mounts, from which some wood may have to be removed to allow the tank to fit as required. Fig. 6-7 shows construction of typical multi fuselage.

Tank tips: Theoretically, the tank location on a stunt machine is governed by the same conditions that apply to U-control flying except that centrifugal force is not constantly present. Although this requires that the fuel line, where it exits the tank, be on a line with the needle-valve body, most multi machines have the tank slightly lower because of nose design which otherwise would be odd-shaped with the usual high-mounted engine. Also, when inverted the tank is high for "richer" running. The main points are to minimize the distance of the tank from the engine and not to get it too low in any case, because a long fuel "draw" leads to leaning out (and overheating) as the motor run progresses and fuel level drops. In rudder-only and similar sport use, an ordinary tank should have its top level with the valve body, although, if space permits, a more consistent engine run results if, say, a third of the

Die-cut parts are pressed from the sheets with the fingertips. The square piece in the middle is plywood.

tank depth is above the valve position.

Installation tips: In most single-channel or sport designs it is advisable to install the actuator(s) and torque or pushrods as soon as possible after the main bulkheads are in place and the sides are pulled together at the tail. It does not matter so much if the nose is completed meanwhile, unless some motor control pushrod modification, etc., prevents it. Consider what you plan doing, changes, etc., before the fuselage is buttoned up.

For example, wiring an escapement which lies deep in a finished fuselage, plus connections to switches, etc., will be so much easier if adjacent fuselage areas (top and bottom) are left open. With the bottom open it is possible to check out a torque rod for binding against fuselage sides — common toward the narrow rear — or to see that it does not rub against a crosspiece or bulkhead, or is not interfered with by knotted rubber.

Balsa pushrods that rub against the structure can be worn through quickly from vibration without the damage being detected.

If the wiring is completed at the same time, the beginner will not be faced later with the discouraging task of attaching wires in just any manner possible. These considerations are necessary because many kits do no more than indicate an actuator position. With so many makes and variations of equipment on the market, the manufacturer of the kit usually does not stipulate a particular system. Details often are lacking.

Cable runs can be positioned and anchored where you want them when top and bottom sheeting is not complete. You will be concerned with dust and dirt getting into equipment installed at this point. Once the escapement or actuator has been installed, it can be removed, if convenient, until final installation; or it can be wrapped with a rag or tissue for protection. It often is necessary to leave in an escapement once mounted because some units require soldering linkage arms in place, or because a torque rod has insufficient end play to permit removal. In multi the trend is to mount servos on a single plyboard; once fitted, it can be removed (as a unit) by taking out four mounting bolts.

Effects of airplane size: Airplane size is a factor which influences construction and materials. The bigger the craft, the relatively weaker it must be if similar materials are used. The tiny model, simply made, can absorb terrific punishment. In general, therefore, the novice should avoid big, vulnerable machines. Balsa is a softwood, and the classic method of gluing pieces together with model airplane cement is less ideal for really big planes since joints more readily tear out adjacent wood. The weight of the wood does not go up in direct proportion to size. A 1/4″ square strip does not weigh twice as much as a 1/8″ square strip, but four times as much. If 4 ounces of blocks are required in a nose, doubling the size means that similar, but bigger, blocks would weigh 16 ounces.

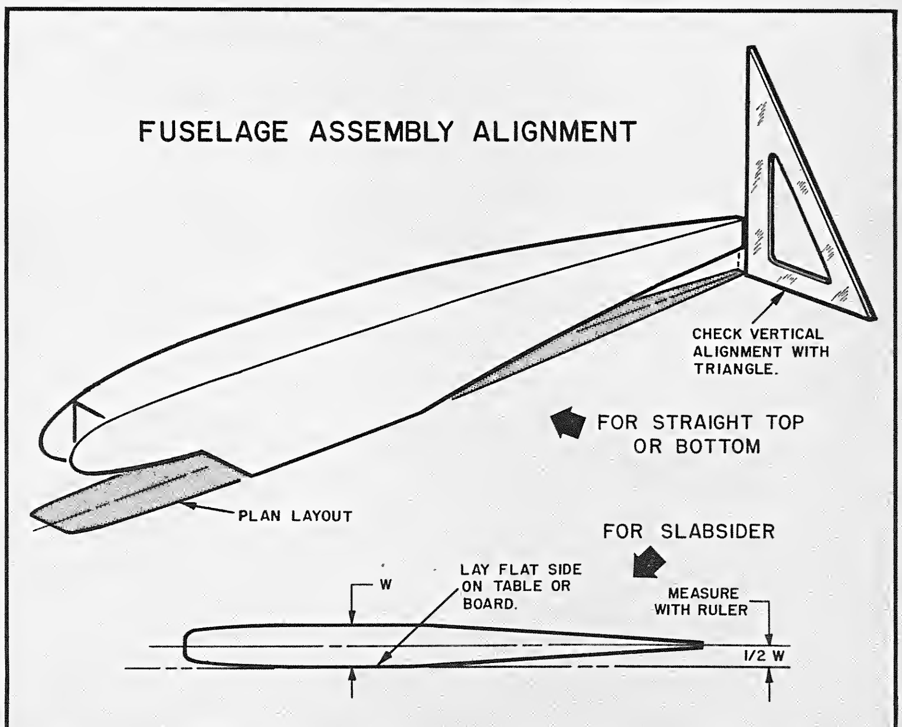
Since, as models become larger, the chance of damage is increased, it becomes increasingly important to anticipate where this damage can occur. The .09-powered craft is not as tough as the .01 machine. The .15 is weaker than the .09. By the time we get into .45 and .60 engines, catastrophic damage occurs in accidents that would be minor for a .15 airplane or of no consequence to the small Half-A.

Where and how do models break? How can we provide a long-lived structure?

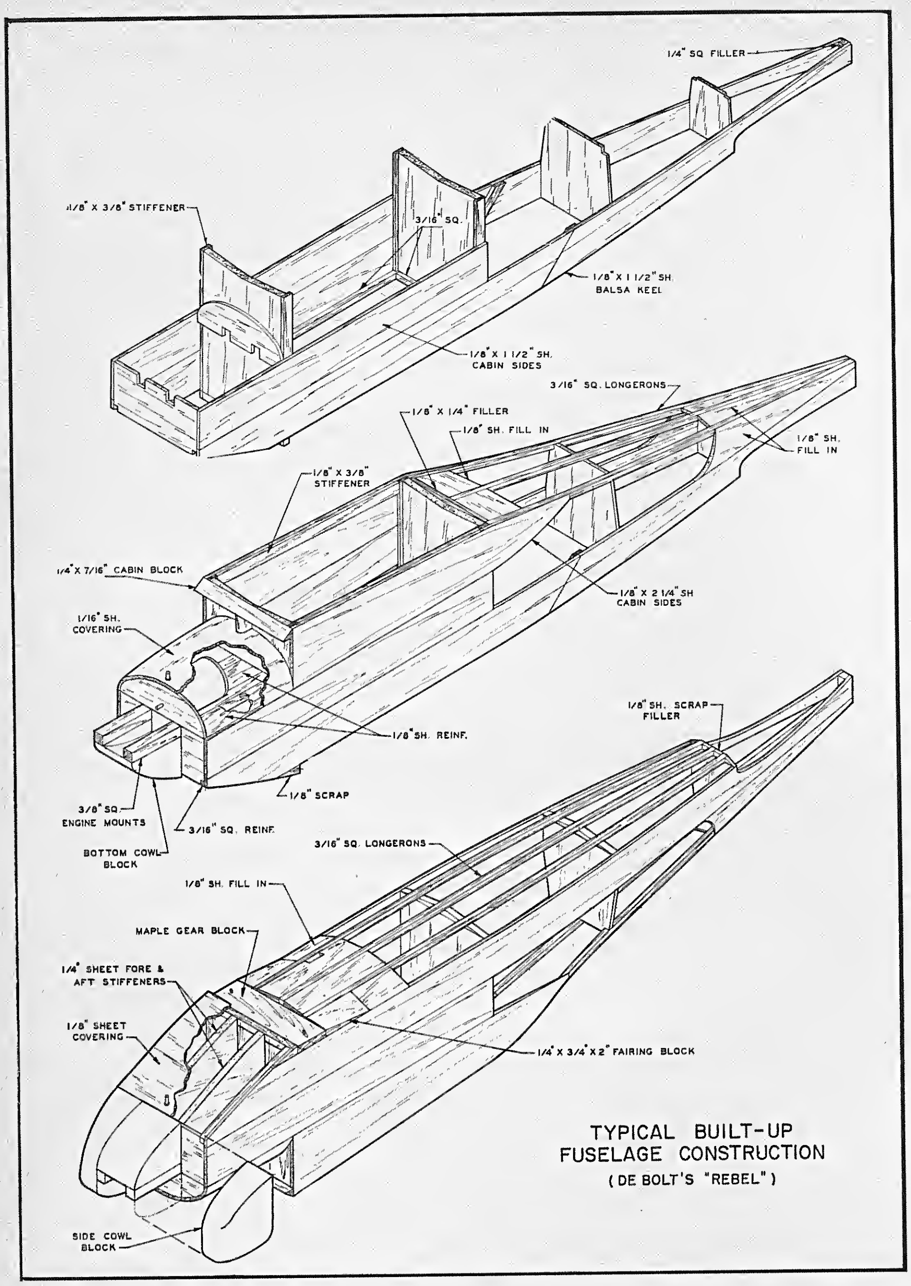
Because the Half-A craft can dive into the ground without crushing the nose, tearing off a tail, breaking a fuselage, or snapping off between wing and tail, construction is simple. If the larger cabin model dives into hard ground, it probably will crush the nose — perhaps back to the cabin. If it hits at a shallow angle so that it skids along the ground or cartwheels, serious but not fatal fuselage damage can occur. Weak points show up. If the tail is glued on, the fuselage will break or crack forward of the tail, and the stablizer usually will break in half. The nose probably will crack at the front of the cabin. The open-topped cabin may begin to break up. Unless the craft was locked into a tight spiral dive — the classic equipment failure in single-channel — the wing probably will fly off on impact without destructive damage.

Strengthening the simple plane: Nose doublers (these examples are recommendations only) should always be used. In very small planes, the doublers can be the same size material as the sheet sides, suitable for up to .02 power. For .049 power, doublers might be the same material as the sides but with two thicknesses of doublers (or one double-thick doubler), with the middle one vertically grained. For .09's to .15's the doubler should be at least double the thickness of the side material, and in larger sizes of planes, still thicker — such as 3/8″ for 1/8″ siding, or two thicknesses of 1/4″ sheet. (Fig. 6-7.) From .049's up it is desirable to run a thin layer of doubling material, grain lengthwise, past the front cabin bulkhead — perhaps back to the escapement position. Above .09 it is not generally desirable to glue the tail on; rather, attach it with rubber bands looped over hold-on dowels, if the design permits.

Always, when feasible, reinforce the top cabin edges (on high-wing types) with lengthwise rails, such as 1/4″ x 1/2″ for a 48″ plane. Arrange wing hold-down dowels so that the wing can slide off easily — front dowels should point toward the nose, but don't angle them too steeply upward, because fuel-soaked rubber can slide off in a pullout. The front dowel that runs



6-1 Two methods for checking symmetrical assembly of fuselage sides at nose and tail.



6-2 **Three stages in the construction of a typical rudder-only fuselage. Top: Sides attached to bulkheads. Middle: Cabin, stringers, and nose partly finished. Bottom: Inverted for bottom stringers.**

across the fuselage will cause the rubber to tear into the wing in a crackup and perhaps rip out the windshield area as well.

The multi plane: In the shoulder- or low-wing, doublers normally extend back to the trailing-edge station, using the same material as the siding, but with grain diagonal. Usually, the fuselage width is just sufficient to drop in the servos, so that there is no room for side reinforcement rails — hence the long doublers.

The nose is filled in, top and bottom —if no access hatch—with soft blocks which are contoured to shape. The failing of ordinary nose construction for multi is the popular slotted motor-mount bearers which slide into corresponding slots in the nose-wheel bulkhead or firewall. On impact, the mounts spread, prying apart the fuselage, which can be destroyed back to the trailing-edge section. This damage can be reduced by running motor mounts through holes in the ply firewall (Fig. 6-8) so that some ply remains outboard of each mount to prevent dislodgement. Lock the mounts together with a hardwood or plywood tie piece, just behind the firewall, screwing and gluing the reinforcement to the mounts.

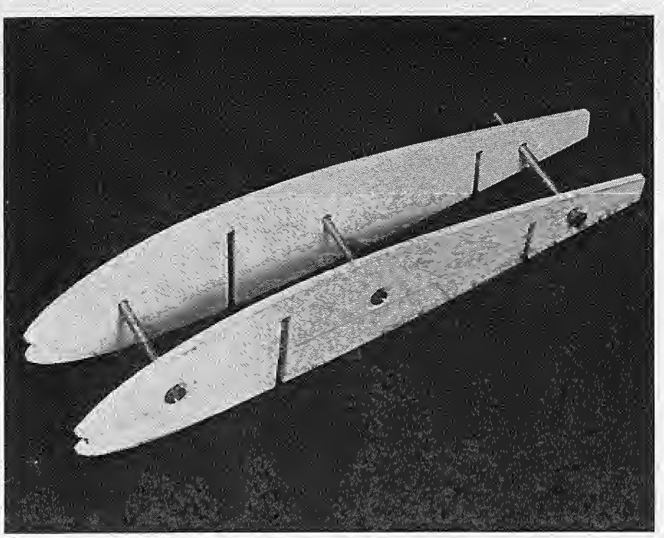
General weak points: In all models there is a tendency, depending on the size of the plane, for bulkheads, etc., to split, permitting the fuselage to open on impact. In all medium- to large-sized craft, precautions should be taken to protect the main cabin bulkheads, especially if they have access holes cut through. In larger sizes, particularly, lightening holes in bulkheads reduce deadweight wood. All that is required is a crosswise member at the top and bottom of such bulkheads — just be sure that the addition does not block the location of wing or other part. For models up to .15 engine size, even 1/8" x 1/4" may be sufficient; or 1/4" x 1/2" for larger craft.

Another failure point is the windshield area in cabin models. Transparent windshields are nice to look at but offer nothing in strength — and the abrupt reduction in cabin depth at this point focuses loads. Unless the transparent windshield is essential, it is better to substitute a soft balsa block carved to the desired shape. When glued in place against the bulkhead and fuselage sides it makes an almost indestructible unit. Any cutouts for windows gravely weaken the structure and, since most modelers simulate windows with white or blue dope, the windshield block can be similarly colored.

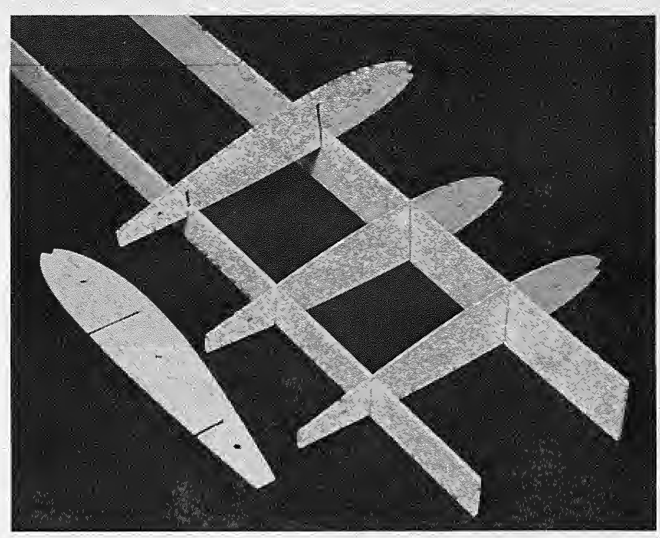
Wood wings: A single-surface sheet-balsa wing is open on the bottom, exposing the sheet-balsa ribs. Sheet balsa of 3/32" thickness can be used, and 1/2" triangular-sectioned trailing-edge material can be added for both leading and trailing edges with spans of, say, 24"-30". In any case, some hard leading-edge beefing-up is desirable. If the all-balsa wing is double-surfaced — covered top and bottom — 1/16" sheet is suitable to, say, 30"-36" span. (Fig. 6-9.) Spars are not required. For single-channel work, the all-wood wing isn't justified in larger sizes, but in multi, the complex wing frame has large sheeted areas and sometimes is totally sheeted, using 1/16" to (more usually) 3/32" material. One advantage of sheet construction is the absence of covering sag between ribs, always present to some degree otherwise.

Single-spar wings: Ideal for small wings and adaptable to medium-sized craft, say 4- to 4½-foot spans. The 26" Lightning Bug is an example. Here, the edges are pinned to the board and the ribs are dropped in place. The single spar, fitting into notches on top of the ribs, offers maximum resistance to bending loads. In such small sizes, the center section need not be covered with sheet balsa, which is common on all wings from .049 powered craft and larger. Weight is minimized, construction simple, strength adequate.

Two-spar wings: Still adhering to open construction — no sheeting — larger wings can be similarly built (adding a second spar to increase strength for greater air loads and antiwarp qualities), as, for example, the Falcon, a sport multi (up to six



6-13 By clamping pieces of sheet balsa between these plywood template ribs, a set of ribs can be made quickly and accurately.

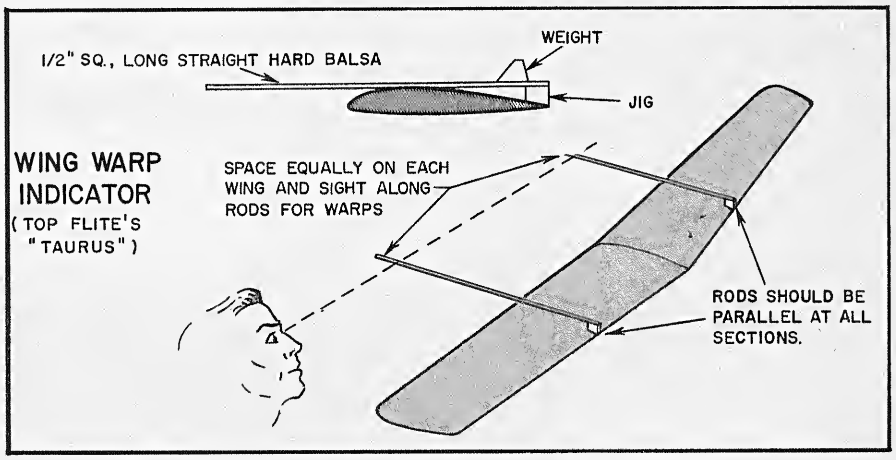


6-14 Eggbox construction used in multi wings. Both the full-depth spars and the ribs are notched. The result is a light, strong wing.

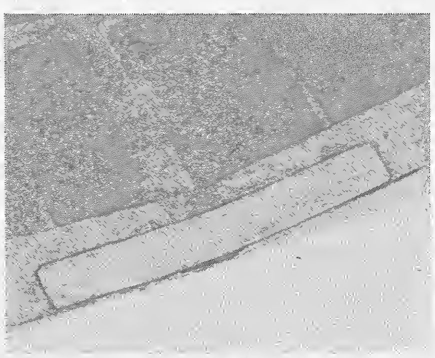
assembly plus large sections of the fuselage bottom.

Tail surfaces: Although simpler to make than wings, the same basic principles of construction apply. The main question is whether the stabilizer should be permanently attached. In a small model this does not matter. For other simple models and most sport flying, a detachable stabilizer (held on by rubber bands which wrap around projecting dowels on the fuselage) prevents damage in landing accidents. Adept pilots with larger multi machines get by with rigidly mounted tails (Fig. 6-23), but almost always the stabilizer is on top of the fuselage for low wings and on the bottom for cabin and shoulder wings. If on the bottom, damage is more likely. There is also the question of whether the entire tail (vertical and horizontal) should be one piece when of removable design — de Bolt Aeronca, Goldberg Falcon Sr., etc. Normally, this is perfectly safe, but it is essential that the designated keying arrangements be followed to prevent accidental in-flight shifting of the tail which could cock the fin. When the stabilizer is fixed in place, a ply reinforcement piece should be glued against the front of the tail trailing-edge spar, or the elevator spar (to which that surface hinges), out to the first rib. This minimizes the common spar break at the fuselage.

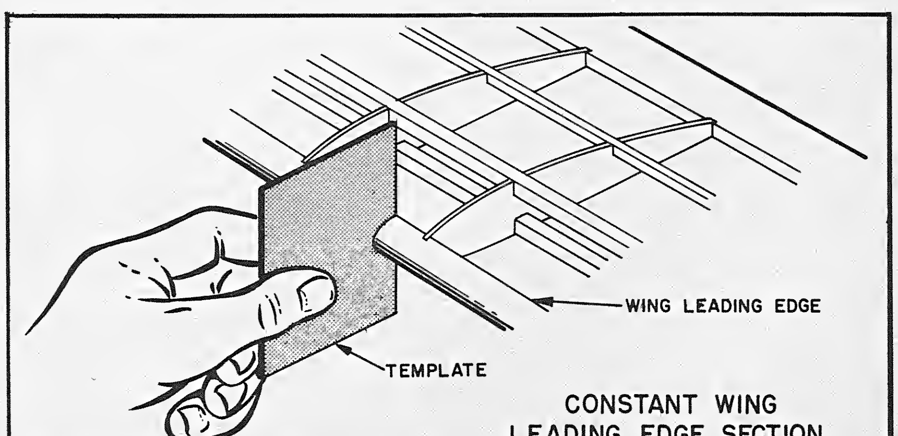
Fins: Although some kits show builtup frames covered with thin sheet balsa, and some designers follow this practice, solid soft sheet balsa is



6-15



6-16 Trailing edges at the center section of a wing must be reinforced with thin plywood, etc., to prevent wing hold-on rubber bands from tearing through the edge material.



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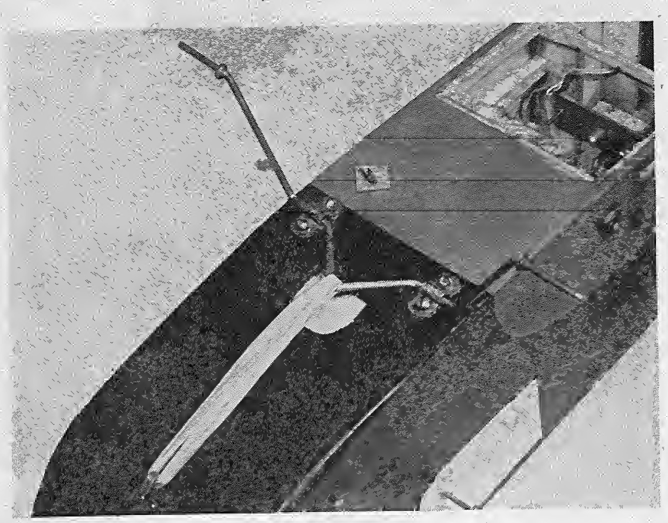
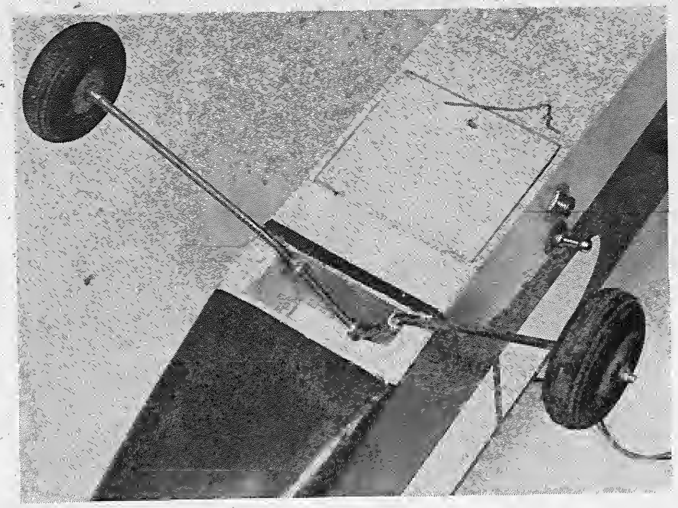
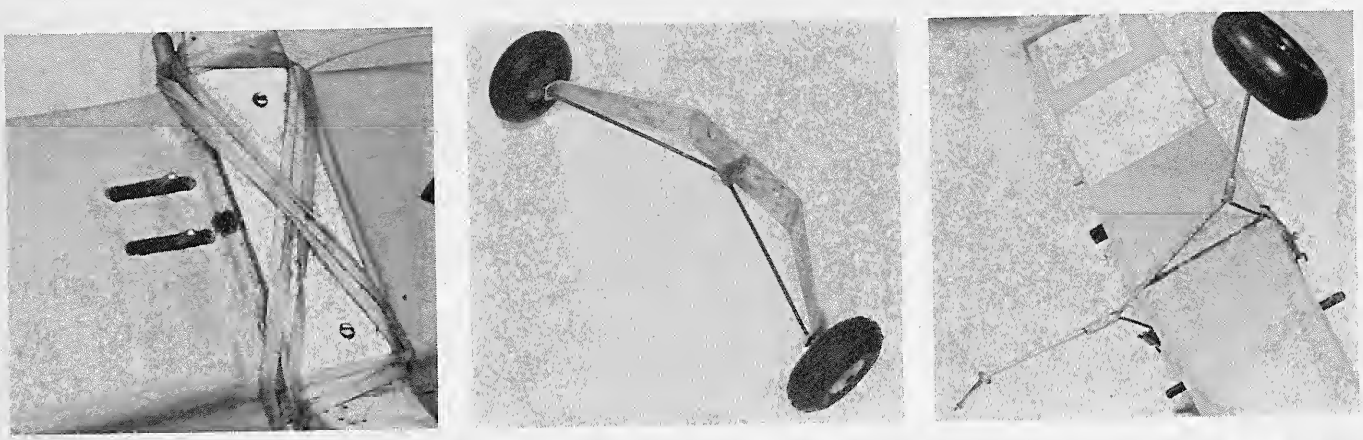


6-18 Shock-absorbing landing gear for .049- to .15-powered planes. One-piece strut hinges in metal strap fittings; rubber bands stretch forward to hook attached to ply firewall.



6-19 Fixed-position landing gear suitable for small sport planes. J-bolts hold wire against a plywood bulkhead. (Portion of fuselage removed in photo.)

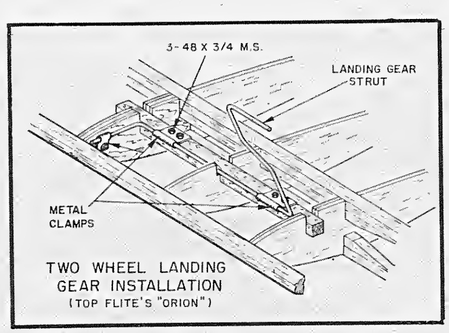


6-20 Removable landing gears (all displace with shock). Left: Heavy-gauge metal on multi stunt model held to fuselage by bands over dowels. Center: When weight causes bent gear up-on landing, steel wire axle restricts spreading. Right: For .049 and smaller craft, wire gear is positioned in slot (hardwood insert) in fuselage bottom; rubber bands keep it vertical.

standard. The fin usually is assembled from two or more pieces of sheet balsa, so that grain directions can be arranged to prevent warping. (Fig. 6-24.) If very soft sheet is used, a hard balsa entering edge may be added to prevent nicks, etc. The fin should be so designed that a projection on its bottom edge penetrates into the fuselage for attachment to a bulkhead — unless the fin is integral with the stabilizer. Frequent use is made of fairing or fillet pieces of soft shaped balsa, glued on either side of the fin at the base and attaching to the airframe.

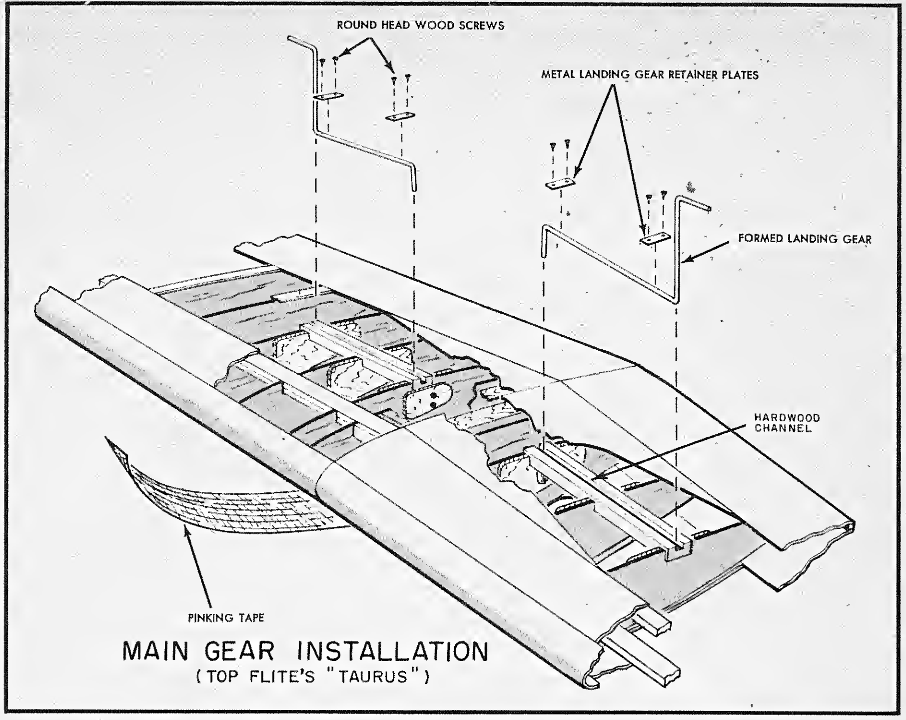
Movable surfaces: The practice of building up elevators, rudder, and ailerons with a spar, a few ribs, and top and bottom sheeting has given way to solid surfaces of soft sheet balsa. If the cross section of the surface, notably standard ailerons, is thick, the builtup method is desirable to save weight. The trend to narrow strip or full-span ailerons utilizes sheet balsa in single thickness.

Some precautions are necessary in attaching the metal elevator horns when the horn is soldered to a rod with each end of the rod bending back at right angles to insert into the wood elevator. If the elevator(s) is cut out at the center, like a real plane with two separate elevators (they move as a unit), it is vital that the angle of each elevator be identical — test by placing the elevator assembly flat on the bench. A slight difference in angle creates mysterious deviations in flight path during maneuvers. If you have the option in your own design, use a one-piece elevator which is not cut out at the center. This will assure that high air loads in severe maneuvers — especially with a control horn attached to one side of the center line (as when a pushrod comes through an exit hole in the side of the fuselage) — won't blow back the end of the elevator farthest from the horn. Slight elevator twist in flight disturbs the flight path.



6-21 One popular method of attaching main-gear struts to a wing for multicontrol models.

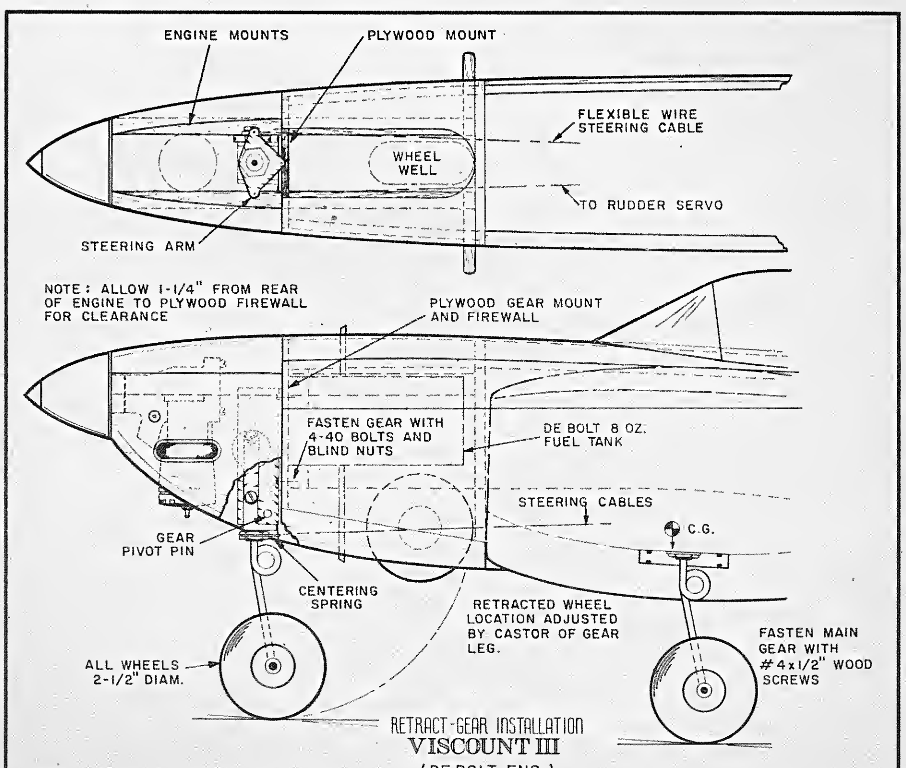
Hinging: Many types of hinging for movable surfaces offer a wide choice. Although a bit unsightly to some of us, the figure-8 stitched hinge using heavy nylon cord (available at hobby shops) is the easiest and quickest hinging possible; and it minimizes binding along the hinge line of a long surface when there is a possibility of deflection of the main flying surface during an abrupt maneuver—or when, unfortunately, a slight misalignment exists in the airframe. Manufactured metal fittings come conveniently

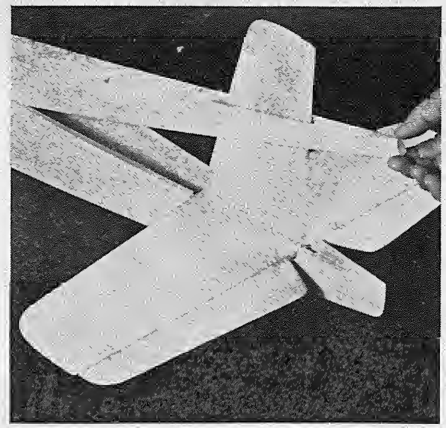


6-22 **An advantage of this method of gear attachment is that struts are detachable and replaceable. Construction is simple, too.**

packaged. Fastidious builders often prefer these metal hinges and fittings. Tough plastic strip hinges exist; these are creased lengthwise to facilitate hinging action. If small individual hinges are used they should be securely anchored to prevent pulling out.

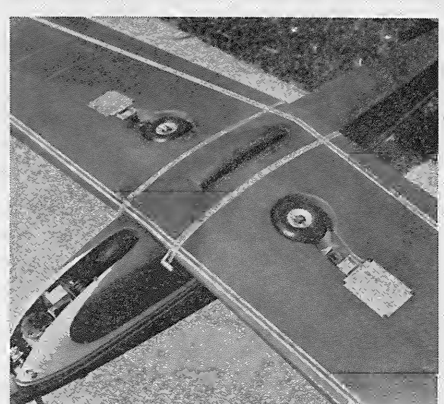
Motor mounting: Traditionally, there are two basic ways of mounting an engine. These are *radial* and *beam.* In the former the back of the engine crankcase has mounting holes which make it possible to bolt the engine against a firm plywood firewall bulkhead. Blind nuts or nut plates (nuts soldered to strip metal) affixed to the back of the bulkhead accept the mounting bolts. In beam mounting, lugs on the sides of the crankcase have four holes through which bolts insert and pass through hardwood engine bearers built into the plane. Blind



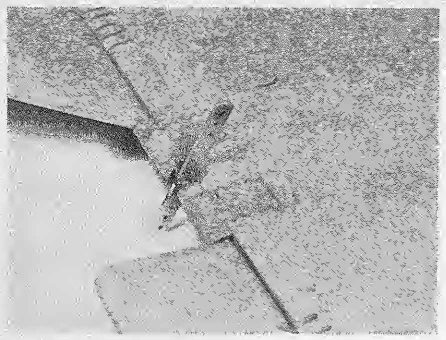


6-23 **Fixed stabilizer mounting in typical multi model. The method of slotting the top fuselage fairing piece to fit over the fin, bracing the fin-stabilizer joint, is unique.**

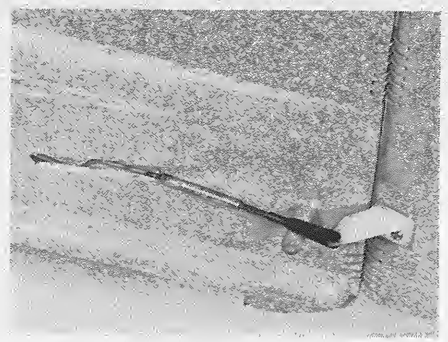
6-24 **Rudder-only linkage. Wire yoke on rudder is adjustable up and down to vary rudder movement. Note Micarta (or metal) bearing for torque rod on stern post. Rubber for escapement stretches through hole for winding.**



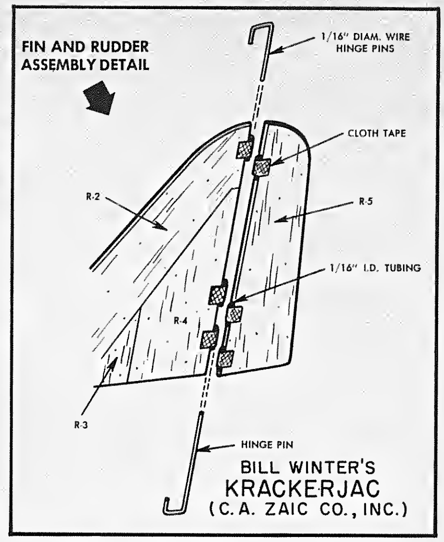
Retractable tricycle landing gear (DMECO Re-Tract Gear). Nose wheel swings back as in the drawing at left; the photo above shows the sideways retraction of the main wheels.



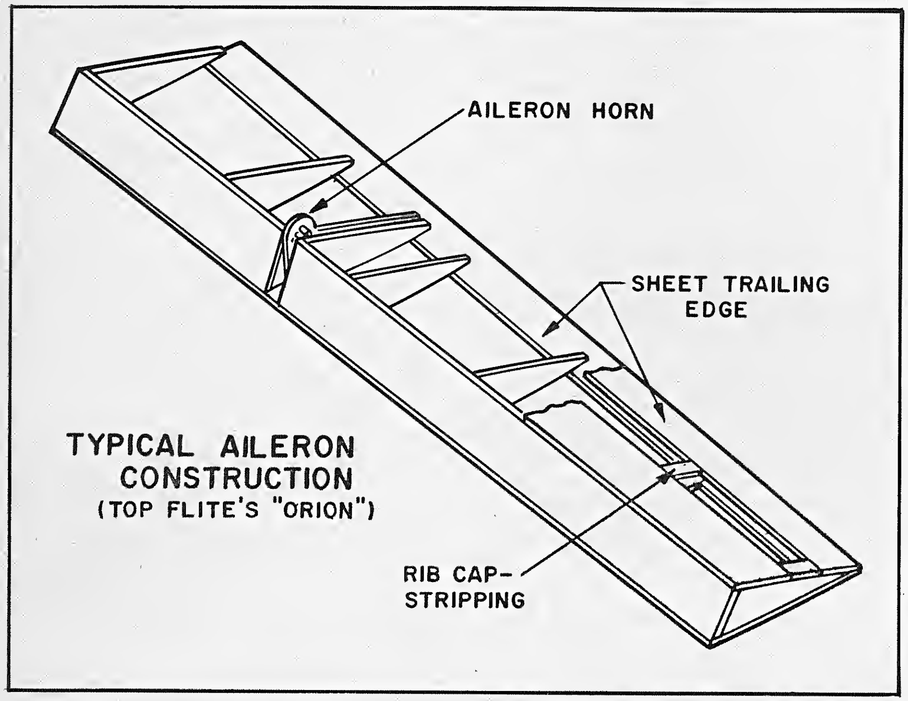
Standard control horn with split elevators. Horn is attached to rod with bent ends which insert into elevators.



Nylon horn and Kwik-Link adjustable pushrod attachment for rudder. Note the figure-8 hinge stitching.



Steel wire (1/32" to 1/16") and metal tube hinging. Pinking tape retainers are glued over the tubing pieces



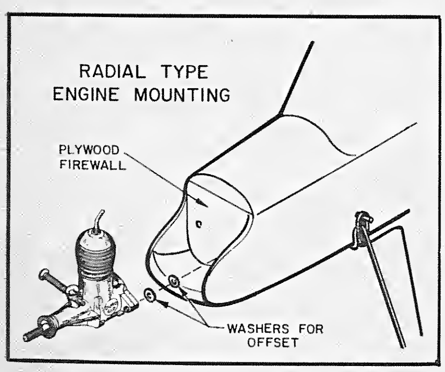
nuts locate under the bearers. Many motors are designed for optional radial or beam mounting.

In general, radial mounting is most common for small engines, notably those of .049 and less displacement, whereas beam mounting is preferred in larger displacements. Special radial-mount accessory items are available for use with big engines.

With beam mounting there is a further choice of whether to bolt the engine directly to bearers, or to a mounting plate which in turn bolts to the bearers. If the plate is used, engines with different bolt-hole spacings can be accommodated by providing interchangeable plates. Offset thrust line adjustments are more easily made and changed with the plate than with a fixed bearer. Plywood, aluminum, and Micarta are popular plate materials. Ply does become oil-soaked, though this condition can be delayed by coating the wood with fuel-proof substances. Metal will not give way in a crackup, but this can cause engine breakage.

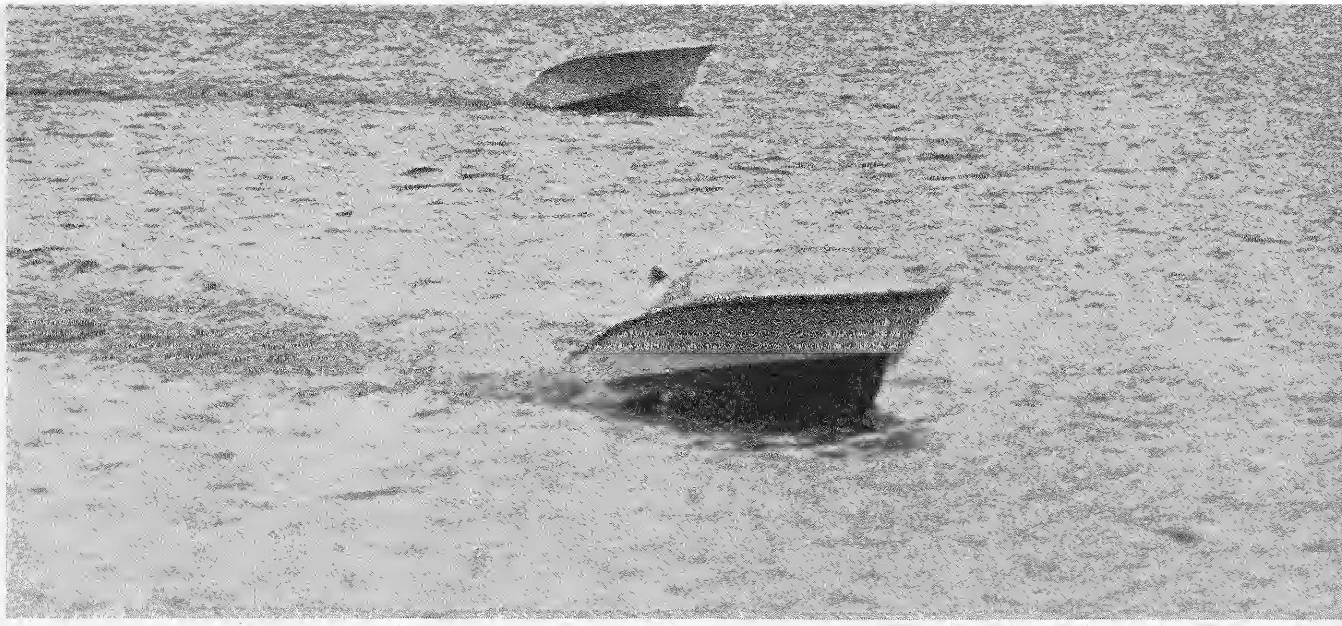
The advantage of fixed bearers is a more streamlined, narrower nose, since the bearers are spaced apart a distance determined by the mounting lugs on the engine. With the plate, bearers are still required to support and fix the plate, and are more widely spaced in order to clear the nuts on the engine mounting bolts. Fixed bearers sans plate are lighter. Bearers are required in both cases, and the plate itself — plus an extra set of bolts and nuts required — is added weight. Without the plate a fuselage can be contoured to flow into the spinner shape. Beam-mounting bearers afford a more substantial mounting which reduces engine vibration, thus avoiding power loss because of flexing of mounting material. It is interesting to note that the original purpose of the mounting plate was to provide a kind of "floating power" through the use of, for example, 1/8" ply with a .35 engine. Since radios now have reduced vulnerability to vibration, soft mounting is seldom required. Nevertheless, the mounting plate is generally preferred for its greater convenience. A crackup will break the plate, saving the engine, whereas the replacement of damaged fixed bearers can be a tedious repair.

Mounting plates are not widely used with displacements less than .15.



Radially mounted engines require blind nuts in plywood firewall. Offset thrust adjustments are made with small washers. Recommended for small planes only.

A .15-sized engine mounted on removable ply plate. Note push-pull action exhaust-restrictor throttle; also note clunk tank. Buried metal tank is also suitable for this cabin sport model.



Racing of radio-controlled hydroplanes is a growing sport conducted under national rules. Here, two gas-engined boats enter a turn.

7: BOATS

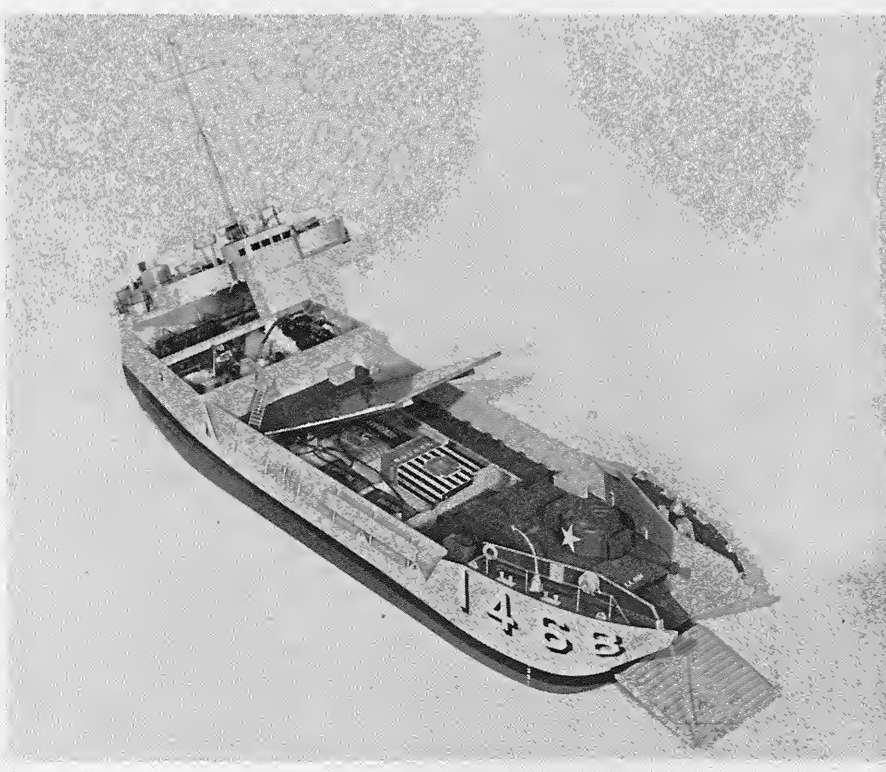
BECAUSE there is so much more to boating than a superficial impression of popular kits suggests, it comes as a surprise to many people that marine work can be as interesting and rewarding as aircraft.

The cliché that boats are good only for folks with high blood pressure is sheer ignorance. Boats can offer the wildest action, if you want it, in the form of fast, high-powered racing craft which compete against each other on closed courses, requiring consummate skill in the use of a throttle and in the manipulation of controls. The racing boat can be as fast as some multicolor stunt airplanes.

Boats offer a tremendously varied choice of projects: in some cases as much of a challenge as a complex airplane in size, type, construction, performance, radio gear and control systems. Conditioned by unique environmental and operational problems, a good boat satisfies the drive of the most restless hobbyist. Of course, some people simply prefer things marine, and are quite content with any slow-moving, realistic boat which offers constant, dependable service. Boats have advantages which planes, as wonderful as they are, simply do not possess.

Not evident in the popular activity based upon standard and familiar kits produced mostly by airplane kit specialists, is the attraction of "dreamboats" to the skilled craftsman. He may be an expert in electronics, or a machinist, or otherwise skilled in an appropriate trade or avocation. To him the boat is a perfect means to a desired end, thus justifies any expense of time, effort and money. He knows that his pride and joy may outlive the family car!

A boat can be more than an electric-motored Chris-Craft or a modified plastic toy. It can be gas-, even steam-, powered, perhaps with a precision-built power plant of marvelous design, appearance, and quality; or it can be custombuilt or assembled from machined or partly machined parts. These impressive craft are not the ex-



This realistic LST, complete with tank, has a motor-operated ramp in addition to rudder control and forward and reverse capability of three electric drive motors.

ception, and many clubs are devoted to them. Other clubs concentrate on racing boats, or a mixed fleet.

Battleships simulate missions, even to firing blanks from cannons. Steam tugs pull a tow — perhaps a rowboat with the operator along for the ride. There are sidewheelers, sternwheelers, excursion boats and riverboats — with all sound effects. Some have animated figures. Submarines — many of them scratchbuilt duplicates of various nuclear subs — even have working ballast tanks. Ocean liners, ore boats, huge aircraft carriers — the possibilities are endless.

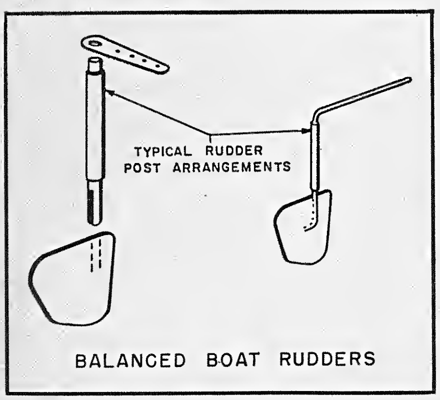
Just as airplane beginners work their way past difficulty levels, boats, too, often appeal to chaps who have never made any kind of a model before, as well as to the veteran who wants a swift PT boat to launch torpedoes at high speed.

For relaxed sailing, scale craft such as this North Star fishing trawler make the most rewarding projects.

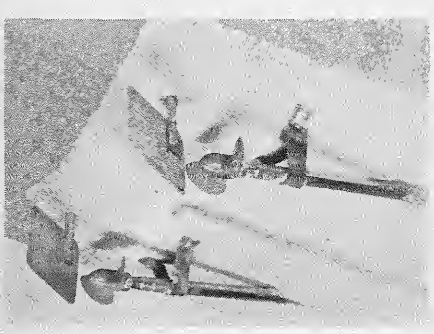
An introduction: The fact that water is much heavier than air is evident in the contrasts between air and marine propellers — in diameter, pitch, and blade area. Or in the relative sizes of air and water rudders, and in the fact that water rudders usually have a portion of their area forward of the hinge line (Fig. 7-1) for balancing purposes (it relieves the load required to turn the surface), whereas in airplane models, dynamic balancing of surfaces is almost never required, and then only when an inadequate actuator is used.

The boat, being less dense (lighter) than the medium in which it operates, is bouyant and therefore requires no minimum speed to operate. The submarine can be operated like a boat but it also submerges. An airplane is submerged in an ocean of air. Unlike the sub, it cannot alter its density by taking on or expelling ballast, and it sinks or tumbles to the bottom of its air ocean when its forward speed falls below the stalling point. Since the boat may stop voluntarily, back up, creep, or dash along — but is not breathtakingly fast except for racing configurations — it does not, in many cases, require the rapid-responding, instant neutralization of selective controls typical of multicontrol planes.

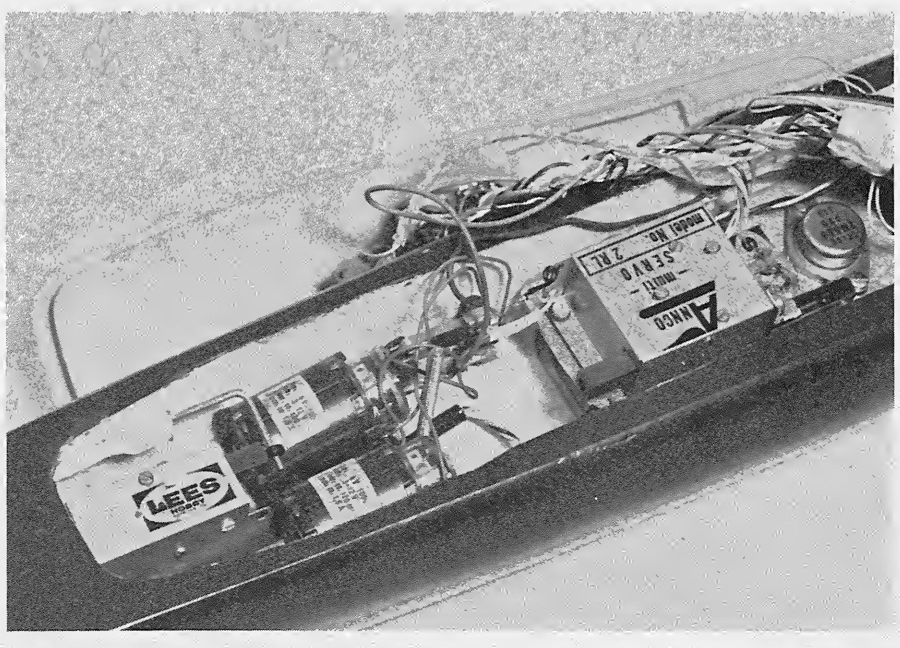
Advantage can be taken of sequential controls which encourage numerous auxiliary functions — blowing horns, raising flags, lowering small boats, turning gun turrets, and the like. While the boatman also benefits from multichannel control with servos that give him selective controls, he is seldom limited in auxiliary sequential operations he may desire. In fact, even sequential operation of a primary control — the rudder — is acceptable on many slower boats. A piloting error, a missed signal, or a skipped control position on a slow-moving tug is almost meaningless. This boatman has plenty of time to "think" his signaling when the vehicle comes toward him —



7-1 Due to the density of water, rudder actuator loads are great, and balanced rudders are used for easier steering — some rudder area is forward of hinge.



Typical twin-screw drive with rudder positioned immediately behind propellers for maximum effectiveness.



7-2 Twin electric drive motors in a submarine. At left is rudder servo; at right, an Annco servo-operated variable resistor and transistor switcher to handle heavy drive motor loads.

causing a seeming reversal of required rudder control. Many airplane operators in the same situation must turn their backs on the craft so that control stick movements are oriented. Boats, like planes, do impose performance limits in relation to what the hobbyist is willing to spend.

In the simpler systems (assuming an appropriate boat) there is a tendency to use steering machines (corresponding to, but more versatile than, airplane compound servos and escapements) which have sequential operation of both primary and (separately) auxiliary control. There is place for familiar proportional systems, appropriately applied. And, where pocketbook permits and performance demands, there is the same urge for multi — though roughly half as many control channels suffice for a boat.

Not only is water heavier than air, but, obviously, it is "wet." Both considerations have bearing on a project. To generalize:

- Even though the boat propeller is small, it imposes high work loads upon the electric motor power plant, often requiring multiple electric drive motors (Fig. 7-2) and reduction gearing — high drive motor loads put heavy drain on batteries, usually an acute problem; therefore large lead-acid batteries are popular.
- Control actuator loads impose restrictions upon contacts or actuators and devices which include contacts for making and breaking special circuits.
- High-current circuitry requires fuse and/or breaker protection.
- Hulls must be waterproof inside as well as out, though many beginners overlook this simple "inside" requirement. (Bilge water in an unprotected interior will swell and distort framework and raise havoc with installations even without direct contact.)

When working with original designs many picturesque subjects are open to the painstaking craftsman — such as this colorful sternwheel excursion river steamer.

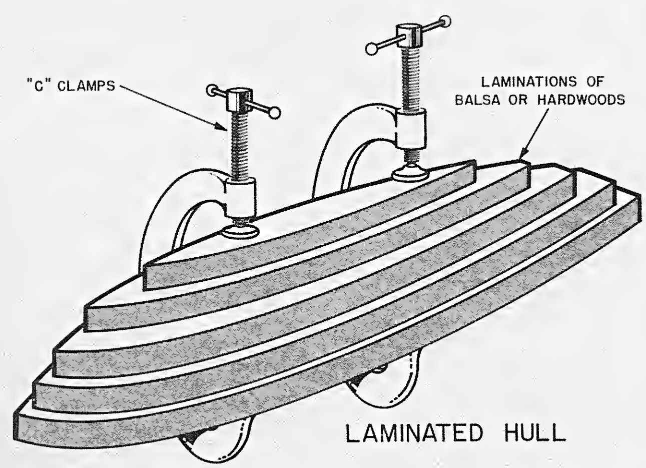
- While it is true that a boat cannot fly away, it can be damaged — even wrecked, if it is fast — either by striking submerged or floating objects, or by lost-control accidents with shorefront obstacles. Thus, in gas-powered boats especially, there is a widespread trend to molded fiberglass hulls and outside fiberglass protection for softwood hulls.

About weight: A boat can carry an amazing amount of equipment, and a very heavy battery load. A plane can carry only so much weight before it becomes sluggish and difficult to fly — a 6-foot plane suffers when it weighs more than 7½ pounds. The Sterling Chris-Craft can support 75 pounds and remain afloat — obviously a capacity far beyond the probable weight of the most advanced installation. A 4-foot submarine, in addition to being heavily constructed and crammed with equipment, can require 30 pounds of lead ballast.

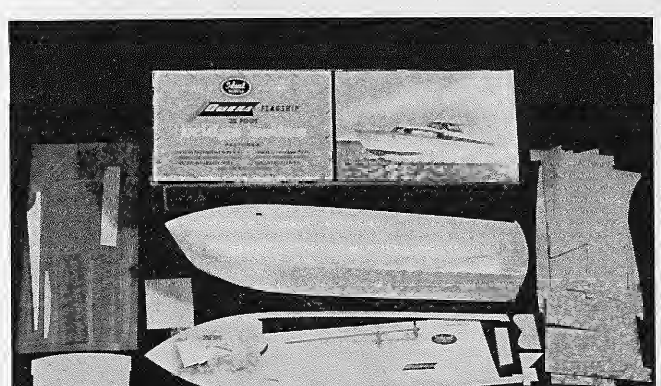
Small boats excepted, there is virtually no limit to equipment that can be carried. An accompanying photo shows an excursion steamer which carries a standard-size tape recorder for sound effects, including calliope and orchestra, bells and whistles. The electronics man invests in substantial gear and systems components. Subminiaturization, printed circuits, the elimination of receiver relays and minimization of electrical demands are not needed in such projects. The hobbyist can build any radio equipment his heart desires. He can use tubes, relays, heavy components, and as many big batteries and motors as he needs. The scope and reliability of functions can be impressive indeed.

Where do you invest weight? In adequate batteries, sturdy construction, fiberglassing; in materials such as plywood, veneers, hardwood, finishing.

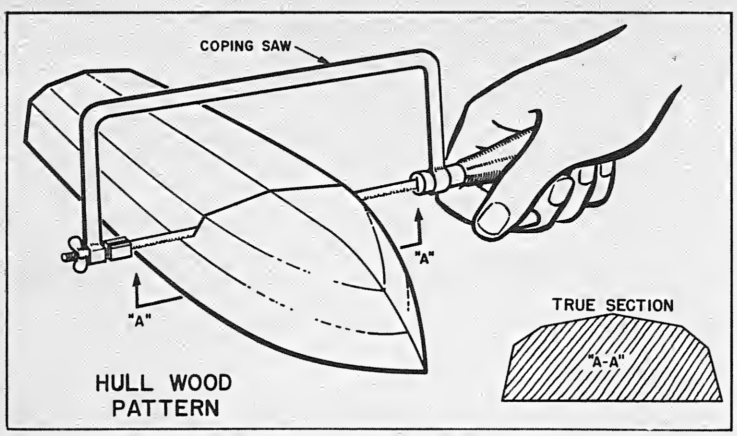
The relative freedom from weight limitations—though not in weight distribution — encourages flexibility in



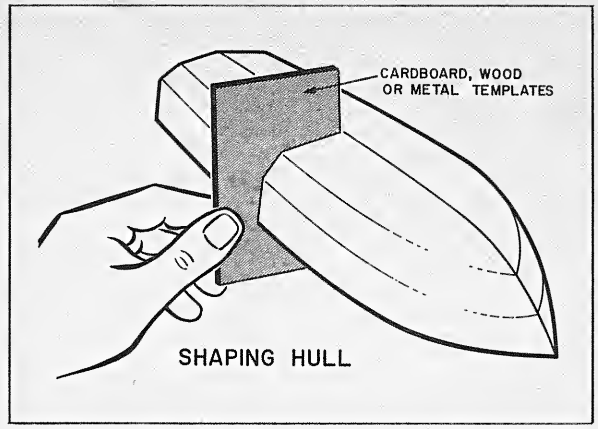
7-3 **How hull laminations, precut to lines, are glued together using C clamps. In a sailboat hull like this one, two or three laminations can be glued at a time.**



7-4 **Many boat kits have formed-wood or molded-fiberglass hulls. This Ideal kit has a partially assembled balsa hull. Kits feature die-cut and shaped pieces.**



7-5 Bulkhead cross sections can be determined by making a dummy hull and cutting it into segments.



7-6 Carved hulls should be checked with section templates while the work is in progress.

choosing materials and building methods. A fiberglass hull is tougher than any made of balsa. Balsa hulls can be glass-cloth (fiberglass) protected. Laminations of white pine (Fig. 7-3) duplicate scale hulls in larger sizes not available in kit form. Any shape and construction can be fleshed out by using any one method or combination of methods. The modeler is not compelled to glue together fragile balsa as he usually is with R/C planes. Various woods, plywoods, fiberglass, plastics and even metal — and epoxy glues — can be used in limitless combinations.

Sources of design: There are four common sources: originals, magazine projects, kits, and conversions of adaptable kits and models, such as plastics. There are ready-to-use boats requiring only installation and power plant. Ordinarily, the skill required is highest for originals — if scale, real plans have to be obtained and adapted, or, in any case, cross sections and lines have to be developed, etc. Somewhat less capability is required for magazine projects which provide patterns and materials specifications. In many lines of kits there is a refreshing trend toward partial assembly — such as assembled, basic sheet-balsa hulls by Ideal (Fig. 7-4), the styrofoam hulls by Graupner, etc. Incidentally, a styrofoam hull will tend to remain afloat in an accident, whereas a thin-walled wood hull which is "holed" can result in a sinking. Emergency flotation can be provided for by cramming Ping-pong balls into beneath-deck areas.

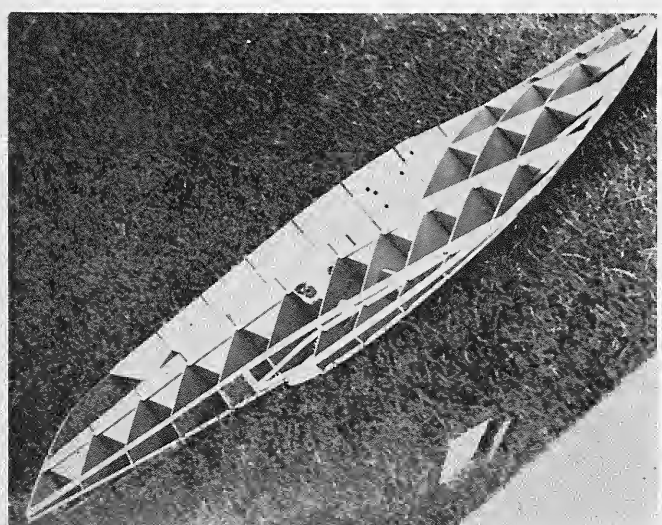
Many plastic models are both realistic and large enough to make possible carefully worked-out radio installations. Some provide for electric drive, and these motors and parts can be replaced with excellent motors and hardware components in the better hobby shop.

Originals: These offer a great selection of types with the great latitude for detailing, size variations and features. But they do require drafting skill to develop bulkhead patterns and hull lines. If the vessel is not very large, one suggestion handles the cross-sectional problem. Carve a hull, or a half hull, to accurate external contours. This mockup can be sawed beamwise at each station and the ends of the resulting segments can be used to transfer the sectional outlines to the template material. (Fig. 7-5.)

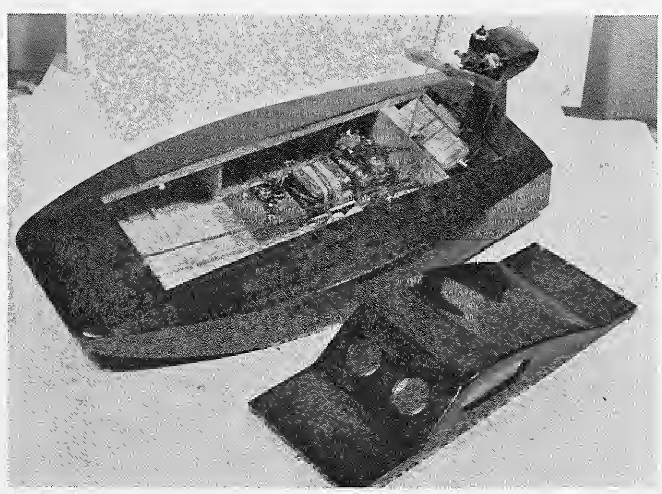
An original calls for an understanding of materials, where and how to use them, thicknesses, and other requirements. An original design might be constructed by 10 people in as many different ways. Three common methods exist for making hulls.

The first is to erect bulkheads, deck down, upon a flat surface, with the framing jigged up as the particular design may require. After framing has been added to tie the structure together, the hull is covered with sheet balsa, thin plywood, balsa stripping, etc. Some flat-bottomed boats can be assembled keel down in the same manner.

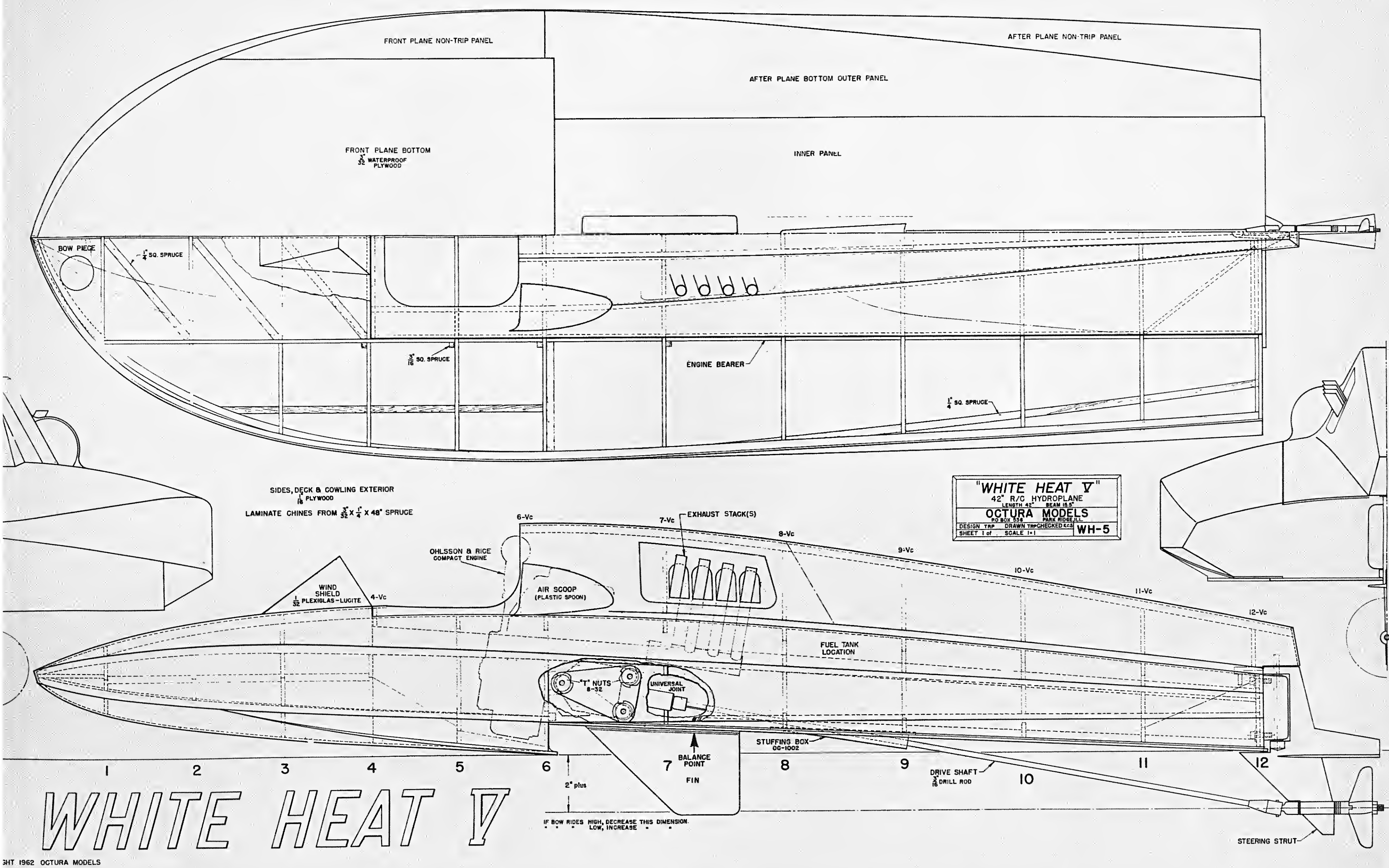
The second is to carve a hull from wood, such as balsa or pine, to the external dimensions — if the boat is



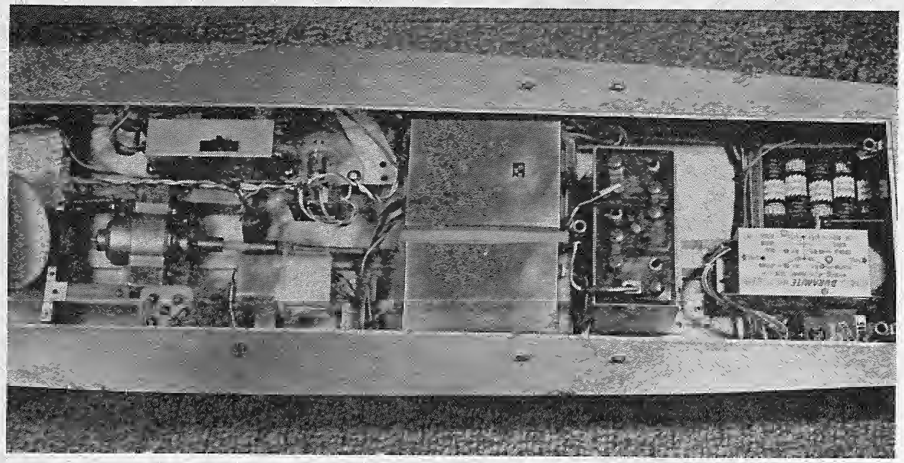
This speedboat hull makes extensive use of plywood for bulkheads and skinning.



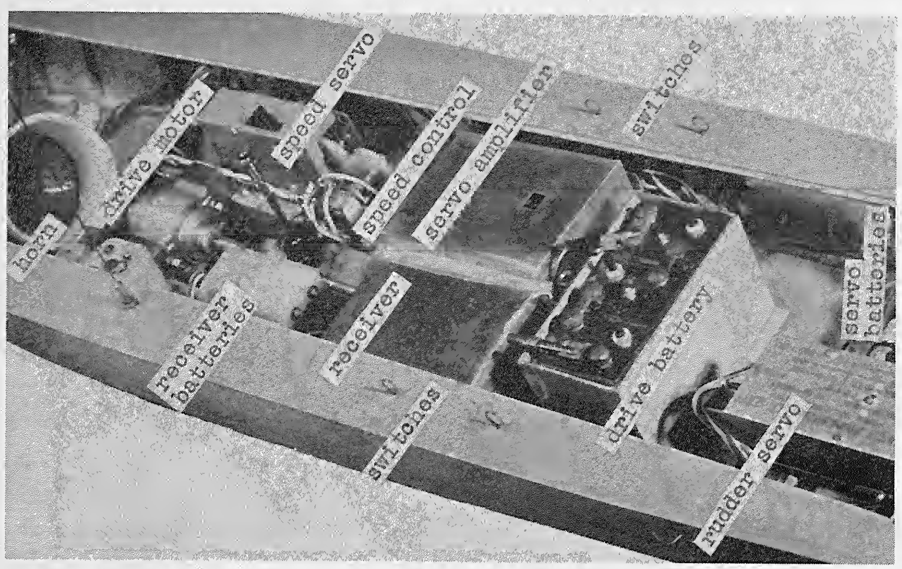
7-8 Airboats — airplane engine with airscrew — are simple to build and fun to operate. This one has unique balloon-type pressure tank to force fuel to engine. Removable structure must be sealed watertight when in place.



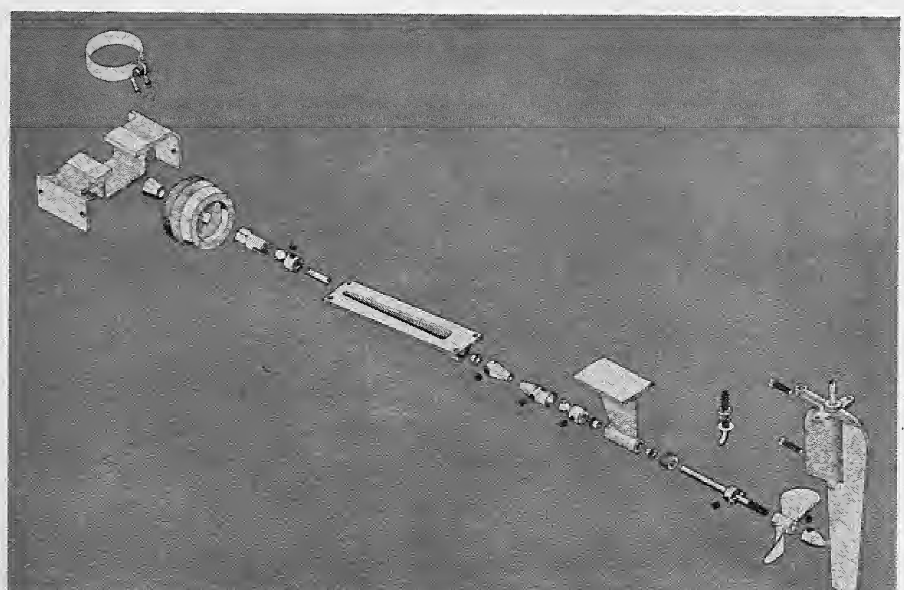
7-7 This partially detailed drawing of the White Heat record holder affords a good impression of the mechanical layout of power plant, shaft, strut, etc.



7-9 Installation on husky bearers of a single electric motor in a scale air-sea rescue craft reveals universal and coupling.



7-10 Another view of the installation in Fig. 7-9 shows horn and, to its right, modified airplane servo with gear train to drive potentiometer for control of voltage and polarity of current to drive motor.



Typical complete hardware system for an airplane-engine-propelled boat. Increasing availability of such boat items recently has contributed greatly to popularity of this sport.

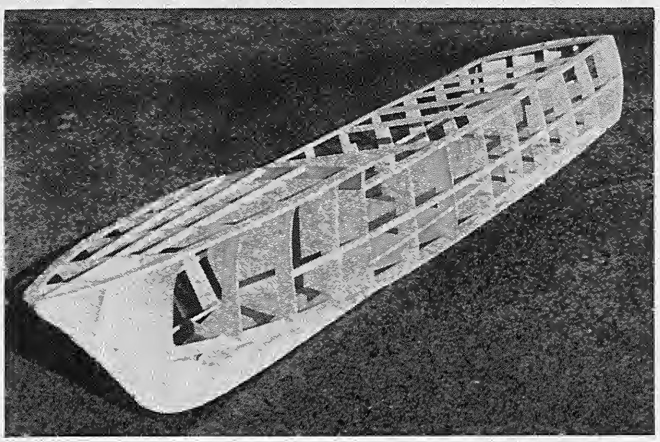
not too large; then carefully to hollow it out with gouges, resting the work on a soft material to prevent dents in the surface. For larger hulls, the necessary number of laminations (pine, usually) can be laid up, gluing them together, with large wood clamps. Each lamination is sawed to external outline — and internal if hollowing is to be done — leaving enough material for subsequent shaping and finishing. In rough-shaping hulls, accurate sectional templates should be used frequently to check progress. (Fig. 7-6.)

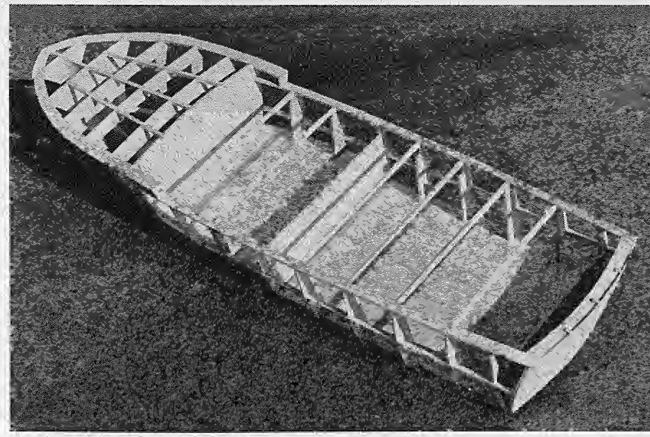
Third, there is the fiberglass hull, which can consist either of a wood hull with glass cloth applied over the surface with fiberglass resin, or of an all-fiberglass molded hull. Fiberglass is tough, hard, fuel proof, and virtually immune to ordinary damage. (See Materials, chapter 3.) When the likelihood exists that more than one identical hull will be made — as in a club project — molded construction is faster and better for many types of boats. Some kits requiring addition of superstructures, etc., have almost-ready-to-use fiberglass hulls.

Published projects: The garden variety of designs that appear in general hobby magazines usually call for a builtup frame consisting of sheet balsa bulkheads and balsa skin or planking, perhaps with lift-off plywood decking with superstructure attached to it. Some larger ones stipulate a laminated wood hull. A very occasional project for the true boat craftsman, such as a racing hydroplane, reveals structure at its best, with materials and design cleverly arranged for maximum strength and installation space without a high gross weight that would cost speed. (Fig. 7-7.)

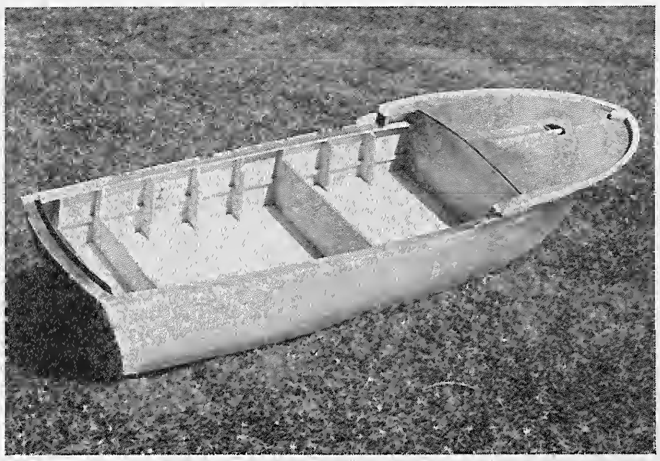
Boat size — kits: Popular general-purpose kits range from less than 20″ to more than 4 feet in length. While many under 18″ have been successfully controlled by radio, 18″ appears the minimum for the practical installation of R/C gear. If we are to consider optional installation of electric or gas-engine drive, 24″ or more length should fulfill most requirements. For more powerful prime movers, 30″ and 36″ lengths are better, while for big gas engines the 48″ size is none too large.

Since the popular basis of the boat hobby is the manufactured kit, it is worth considering an experienced dealer's viewpoint. Assuming you have never made a boat, he will ask you what kind of a boat you would like to make and explain the popular categories in sizes and prices. He should take time to explain the methods by which the boat can be controlled, and his suggestions will be geared to your capability and pocket-





Typical stages in the assembly of a 40″ Sterling Chris-Craft cabin cruiser. In this model by John Schneider the balsa siding has been fiberglassed for added strength.



book. He will point out the pros and cons of electric and gas-engine drive; will show you what is needed for accessories and hardware — if the kit contains none, or if what it contains should be replaced with something superior.

It is possible that he will suggest separating the project into phases and will recommend against buying all equipment (including radio, actuators, batteries, etc.) simultaneously.

Rather, he may suggest — should you seek advice — that the boat be assembled to the point where the motor or engine has been installed, including drive shaft, stuffing box, mounting brackets, etc.

The builder will want to consider if he will be limited to single-channel. If so, and drive motor drain approaches 3 amperes (stalled), he must install special relays between the drive motor and an actuating device such as the Boatomatic.

Multi, we have said, offers advantages. Remember that here, too, a switching device will be required for the drive motor. In airplanes, relayless receivers are the vogue, but many a second-hand relay-type receiver is excellent for a boat.

The dealer is likely to place boats into three categories:

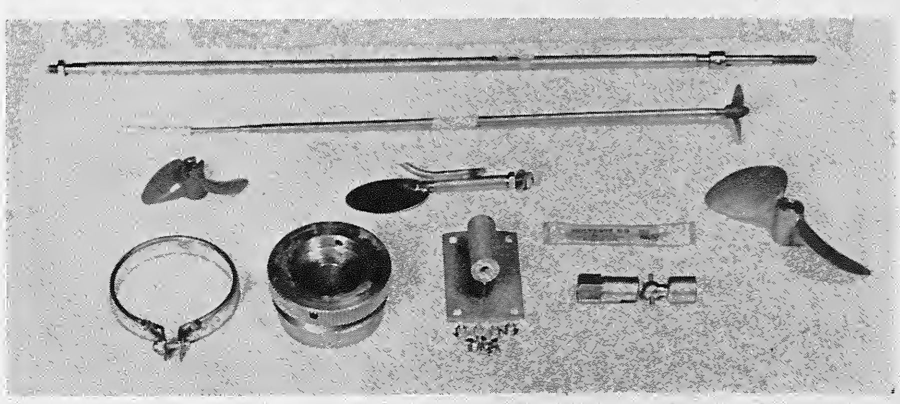
- Sport: runabouts, cabin cruisers, etc.
- Commercial: shrimp boats, freighters, tugs, and so on.
- Military: battleships, PT boats, destroyers, etc.

He will lump together special and off-beat things: air boats (Fig. 7-8), which have an airplane-type prop and skim the surface of the water; submarines, sailboats.

- Racing hydroplanes.

Not only does the new boat builder have an urge to try something nautical but he wants, or thinks he wants, to "really build something." He expects to work, often to enjoy the fabrication of the craft more than its actual use. The average boat kit builder seems not to have had the long exposure to kit contents that is usual with plane builders, who, in the R/C field, are not overwhelmed by the sight of a pile of lumber.

Shown an imported Vedette (a cabin cruiser with cutout plywood bulkheads and hardwood parts — an easy and delightful project), he may draw back. The dealer might then show him one of the splendid Ideal kits, such as the 20″ Sportsman. These kits have an assembled balsa hull — not a hol-



These samples of boat hardware items at the hobby shop hardly suggest the great number and variety of parts that are available.

low shaped block, but an accurate, glued-up hull with sides, bottom, stern and nose block in place. It, too, includes cutout ply bulkheads, but it is partly assembled. In the Ideal line there are other assembled-hull kits for different sizes — 30″ shrimp boat, 36″ Coast Guard patrol boat, 42″ sports fisherman. Other companies have lines featuring their own special features.

Not exactly duplicating either of these samples, builtup balsa hulls — typified by Sterling kits from cruisers to freighters — receive a strong play. So, within these basic divisions, structurally speaking, most needs can be met — according to how much work the hobbyist truly is willing to do.

Placement of components: The layout of equipment must satisfy both physical and electronic requirements. The tyro, finding that the location of the power plant is automatically determined by the specifications of the prop, shaft, etc., then tends to scatter radio, servos and batteries in any convenient location. A more organized, grouped installation is necessary. Placement of heavy objects, notably the wet-cell batteries for an electric drive motor (which must be accessible for inspection), affects the trim of the boat. If the weight is too far forward the boat may "plow" when running. (Trim with lead ballast.)

Pictures with this chapter suggest approximate locations of systems components. (Fig. 7-9.) One tip is to make a box for the batteries longer than required so that the batteries can be neatly shifted fore or aft. Since electrical "noise" is an ever-present problem in the electric boat, the location of receiver, motor and actuator is important. (Fig. 7-10.) The receiver antenna should be taken through the deck as close to the receiver as possible, never carried back through the hull in proximity to other wiring or noise-generating components. Never place the antenna near the power cable.

Operating hardware: Accompanying pictures and charts show recommended sizes of flywheels, propellers, shafts, couplings, universals. The subject is much too big to cover in detail in a general R/C book. Try to use quality items, even when some makeshift item seems to do the job. For example, all props are not alike, even when the pitch and diameter are the same. There are cases of boats which barely moved with one prop, accelerating to good speed with one more properly chosen or one of better design and manufacture. Accurate alignment of operable parts is essential. Poor alignment — as in a coupling or shaft — consumes power. With electric drive this translates into lost thrust, higher current drain, and shorter battery life. Current drain may be so high that a short circuit will be suspected, or a battery may be thought defective. Be sure that everything is perfectly lined up and operating freely.

MODEL 10005 Pittman "Boatmaster"

	8 volts	10 volts	12 volts	
No-load speed	4500	5600	6700	r.p.m.
No-load current	0.63	0.65	0.80	amps.
Full-load speed	2550	3900	5000	r.p.m.
Full-load current	3.50	3.50	3.50	amps.
Full-load horsepower output	.0158	.0232	.0309	h.p.
Efficiency	42	49	55	%

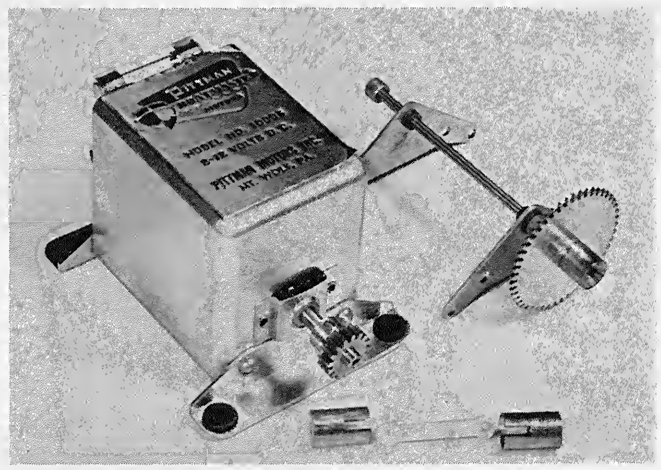
Max. safe operating current 3.5 amps.

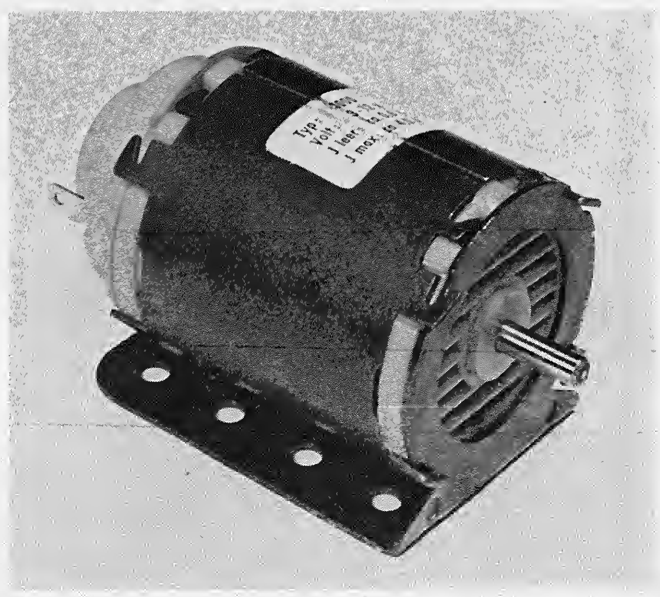
Comparative speed when loaded with Fisher three-blade cast bronze propellers operating in static tank:

	2:1 gear reduction — 2½" dia. prop.	
* 8 volts	1100 r.p.m.	3.0 amps.
	3:1 gear reduction — 2½" dia. prop.	
8 volts	850 r.p.m.	1.9 amps.
10 volts	1150 r.p.m.	2.6 amps.
12 volts	1350 r.p.m.	3.1 amps.
	3:1 gear reduction — 3" dia. prop.	
8 volts	850 r.p.m.	2.6 amps.
*10 volts	950 r.p.m.	3.5 amps.
	4½:1 gear reduction — 2½" dia. prop.	
8 volts	750 r.p.m.	1.0 amp.
10 volts	950 r.p.m.	1.4 amps.
12 volts	1100 r.p.m.	1.8 amps.
	4½:1 gear reduction — 3" dia. prop.	
8 volts	700 r.p.m.	1.4 amps.
10 volts	900 r.p.m.	2.1 amps.
12 volts	1000 r.p.m.	2.9 amps.
	4½:1 gear reduction — 3½" dia. prop.	
8 volts	600 r.p.m.	2.6 amps.
*10 volts	700 r.p.m.	3.5 amps.
	4½:1 gear reduction — 4" dia. prop.	
8 volts	475 r.p.m.	3.2 amps.
	6:1 gear reduction — 3½" dia. prop.	
8 volts	500 r.p.m.	1.8 amps.
10 volts	650 r.p.m.	2.4 amps.
12 volts	750 r.p.m.	3.2 amps.
	6:1 gear reduction — 4" dia. prop.	
8 volts	425 r.p.m.	2.3 amps.
*10 volts	550 r.p.m.	3.2 amps.

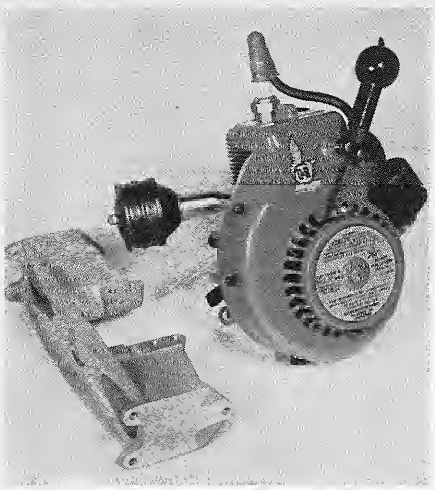
*Values above voltage listed may exceed safe operating current.

It should be noted that above currents will decrease and speeds increase when actually installed in boat in motion. Above values serve only as a guide to possibilities attainable. Actual experimentation is necessary to arrive at best conditions for any given hull.

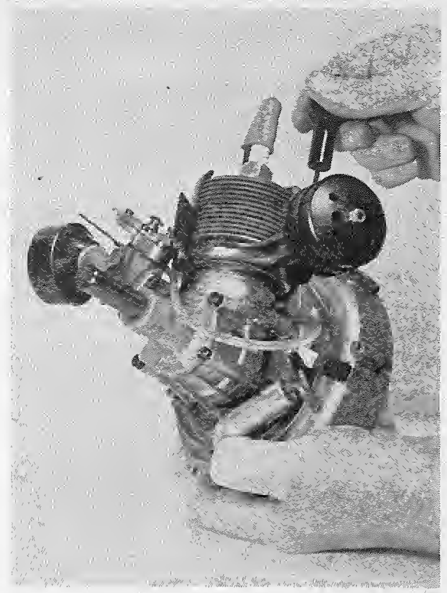


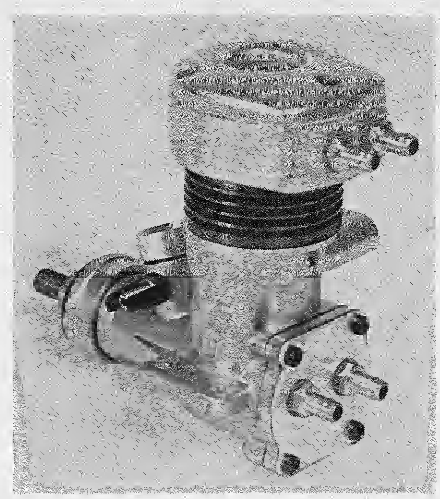


7-11 **Two popular types of electric drive motors. Top: Pittman (fused, note top back of motor) with selection of gear trains (one shown) and drive shaft universal. Bottom: Monoperm (which comes in a number of sizes).**



7-12 For racing use, the O&R Compact ignition engine includes an easy-to-use pull-cord starter.





An OS marine motor adapted from an airplane engine. Note fittings for circulation of cooling water.

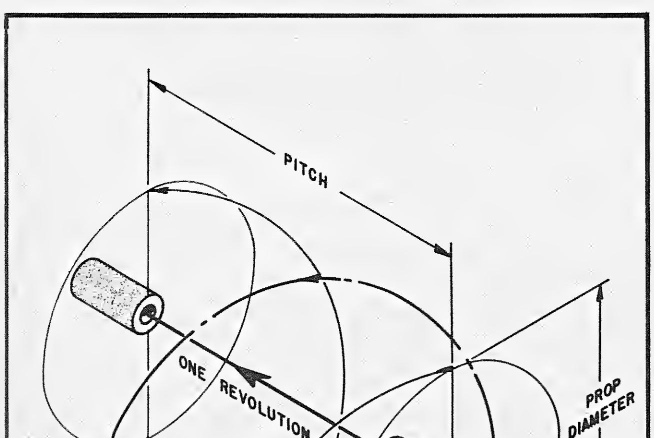
Propellers: Most boat fans have a fairly good idea of propeller diameters to be used with electric drive. Literature lists this information. For example, Pittman provides such data for the popular Boatmaster Model 10005 at 8, 10, and 12 volts input. The chart relates various gear ratios (reduction) to prop diameter, giving amperes drawn and the r.p.m. This chart, reproduced in this chapter, is based upon Fisher three-blade cast bronze props operating in a static tank.

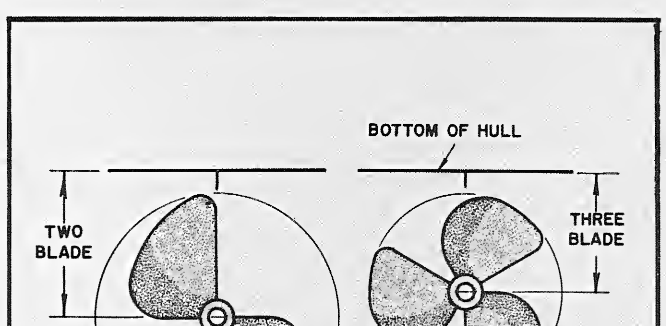
But how do you find prop specifications for a gas engine? Octura advises to determine the stroke of the engine, then multiply it by 2.00 to 2.50 for the approximate diameter of a two-blade propeller. (A three-blade prop of equivalent pitch would have 80% of that diameter.) The flywheel should be roughly of the same diameter as the prop, and its thickness about one third that of the diameter. Since different boat types naturally have different propeller requirements, a ratio of prop diameter to pitch of 1:1 to 1:75 gives a prop that permits throttling down without stalling the engine, at the same time affording good speed at full throttle.

On heavier boats, begin with smaller diameters and lower pitch to avoid overloading the engine. If the engine then is too lightly loaded, increase the diameter. If the shaft angle becomes too great for efficiency due to propeller diameter, move the prop back; or use an articulated drive (universal joint) which places the prop shaft parallel to the water surface; or use a three-blade prop. If the prop diameter required by the boat size, type and weight is too big for the engine, either a larger engine, or a geared-down arrangement, permitting the larger prop with the same power, must be used.

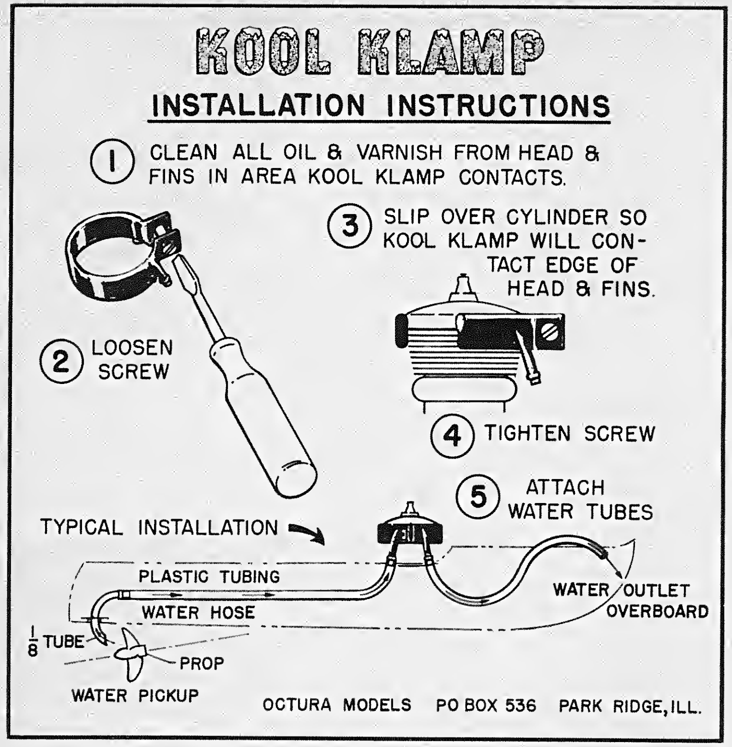
Motor and engine sizes: Both electric and gas power plants come in many sizes. However, the lower end of the power scale is not too useful, because adequate radio and hardware installations usually mean larger boats and power plants. Among electric motors the Decaperm and Aristo No. 5 (approximate equivalents) and the Monoperm and Pittman 10005 (also roughly equivalent) (Fig. 7-11) are widely adaptable. In gas, the little .049's are sought out for extremely simple and small craft, but the high end of the scale — .35's, .45's, .56's, .60's — are in demand (speed and power are synonymous).

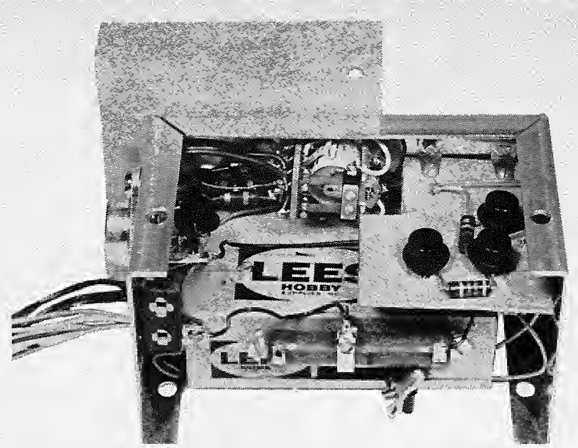
Electric or gas? Each has pros and cons. The electric motor is simply installed, has little or no vibration, is switch-operated, and starts instantly without fussing. It is cleaner and, in a majority of installations, more appropriate to the type of boat. The gas





Selection of prop diameter and pitch is most critical in a boat. When a two-blade prop compels an exaggerated shaft angle, a three-blader will place shaft closer to hull. Special struts and universal couplings provide another solution to the problem.



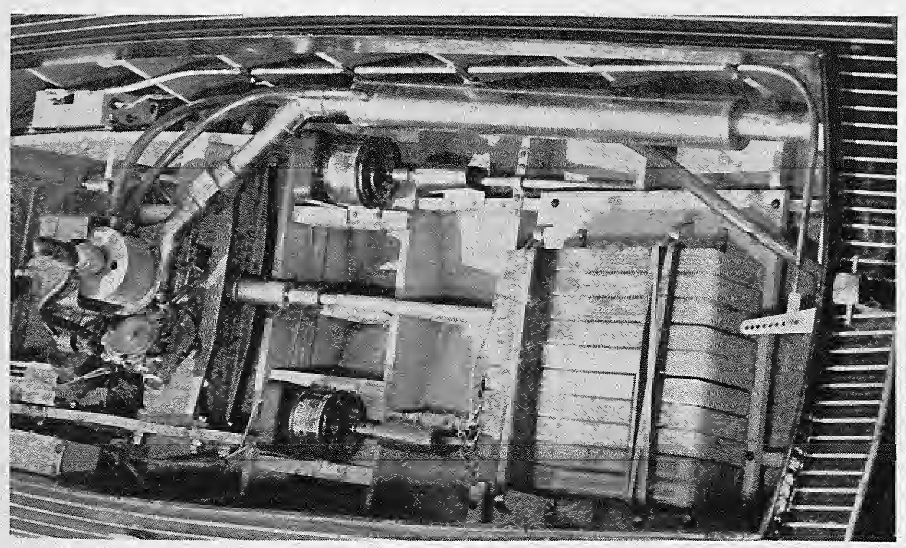


Handling of electric drive motor current loads is a constant problem. This custom switcher uses Duramite servo to operate slide resistor which ties in with relay and transistor circuitry. Normal relays and transistors in model radios are not intended for such high-drain usage.

7-13 **Airplane engines mounted inboard almost always require forced water cooling, achieved by a water circulation clamp around the cylinder head, and the pickup and outlet system here illustrated.**

engine is used for fast boats, for racing types as a rule; otherwise only in open-top runabouts, etc. Gas engines usually must be pull-cord-started and, if the boat is of the enclosed type, a removable top ordinarily must be removed and replaced every time. The Ohlsson & Rice Compact (Fig. 7-12) has an exceptionally easy to use pull-cord starter — but is appropriate only for big boats, such as the Sterling 42" Korvette or one of those large fiberglass-hull jobs; or for racing, as in Octura's White Heat record-holder. The electric motor (or motors) requires use of large, rechargeable batteries, normally lead-acid type. Since there are radio and servo batteries as well (often nickel cadmiums having different charge rates), the active user really needs a charger that can handle mixed charging problems simultaneously.

Some electric-drive installations run 3 to 5 amperes of current; under stalled conditions, much more. Since such loads begin to compare with some household branch circuits in capacity, it becomes necessary to have protective fusing, or circuit breakers. Too many operators put tin foil in a fuse holder rather than give up on a day's outing when trouble arises. This often results in a stalled boat smoking in the middle of a lake. The breaker that requires resetting in order to continue operation is insurance against burned-out equipment — or worse.



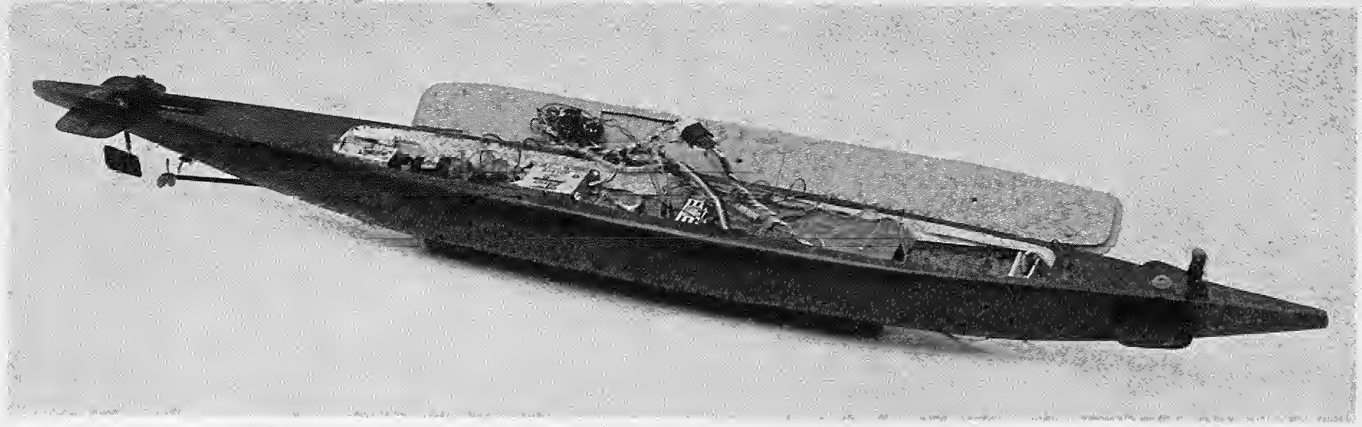
Muffler (top) for O&R Compact engine in Al Seidenberg's boat is made from plumbing waste tubing machined to fit. Muffler contains fiberglass cloth instead of baffles. Note that water-cooling line from cylinder empties into muffler to cool it also.

Any persistent trouble should be corrected.

Gas engine vibration is a severe condition that limits the type of actuation: complicated and dainty gimmickry won't operate well when shaken up. Hulls must be well made. Wood motor mounts, etc., should be epoxied in. Ordinary cement for this purpose is taboo. Hardwoods, nails, and screws as well, should be employed on appropriate parts. If the hull and installed construction won't handle sustained vibration, results will be disappointing.

The gas engine cannot be reversed without complicated gearing, etc., which is limited to a machinist. Water cooling (Fig. 7-13) is highly recommended for boat engines which are adaptations of airplane engines. Small fun boats of the runabout type may get by with airplane Half-A engines running in the open, as might some bigger craft, but overheating is always a problem. Some manufacturers produce water-cooled versions, or engines with head and/or case water-cooling. Octura makes the Kool Clamp water jacket for the cylinder head. The O&R Compact has blower cooling, also comes water-cooled.

Plumbing is required for water cooling. Usually, there is a pickup tube right behind the propeller, which forces water to the cooling jacket, etc., with an exit return tube just in front of the prop. Thus, even when standing with motor running, there is a forced circulation of water. For cleanliness, or when engine noise is not realistic in a sport craft or is an objection at some operating site, a muffler and exhaust piping may be



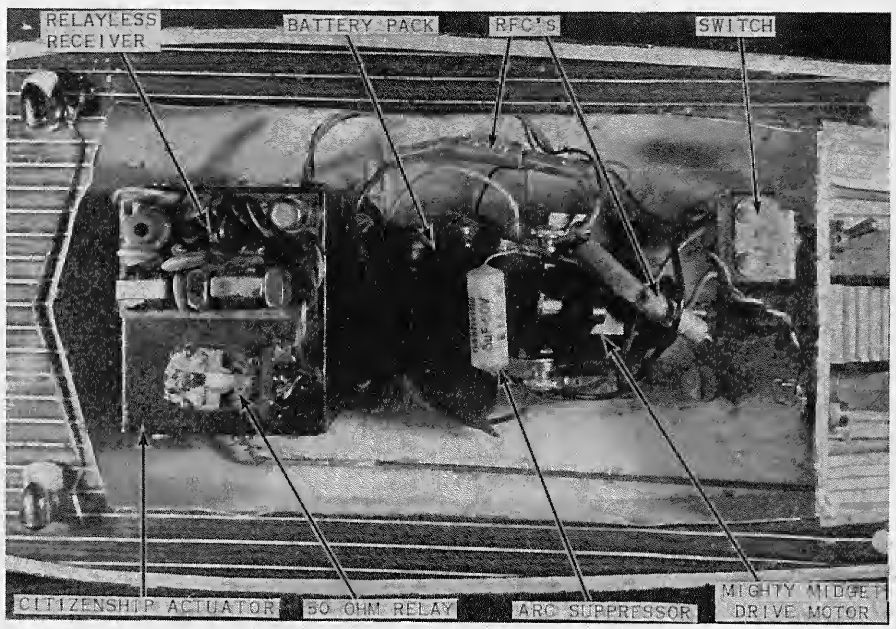
Submarine built from Graupner kit. Conning tower and superstructure are removable for access; shown here folded back.

required. Several marine accessory and engine manufacturers have muffler items.

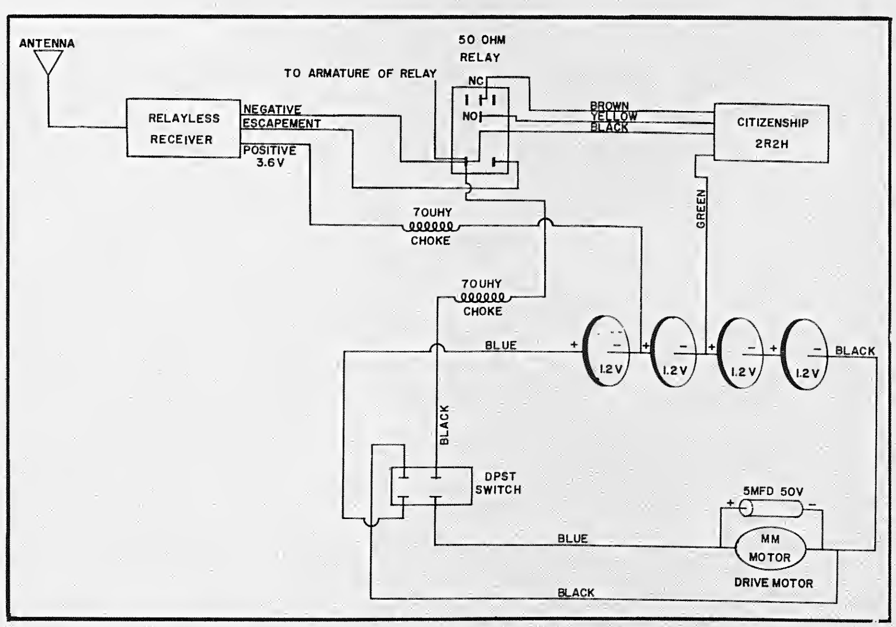
Some kit limitations: Manufacturers of boat kits often include hardware. In many cases the hardware necessarily is of the simplest and cheapest type, such as steel wire for a shaft, brass tubing for a stuffing box (it depends on grease packing to keep out the water). For best results it is desirable to select hardware put out by specialists in the field: Enya, Octura, Graupner, Fisher, etc. The additional expense will prove to be a sound investment.

Kits often illustrate a gas engine — or optional gas-electric — installation simply because it is assumed customers expect to see such an engine in a boat. The arrangement may not be ideal, nor even very good; and, in fact, in most cases an electric drive is superior for the particular model. When electric drive is stipulated, many large boat plans show one motor when two or even three are required for performance. There is a fear that if a boat kit is revealed to require two motors when one would make it go, the consumer might decide against the kit because its completed cost will be higher. Most unfortunately, radio and systems gear shown or recommended may be capable of operating one electric motor, but two motors can overload and damage actuating equipment. The reader is warned, therefore, that when he switches to multiple electric motors, as he may have to, he must analyze the entire electrical system: its drain, battery requirements, actuator capabilities. Popular switching devices and actuators often have lightweight contacts which will burn up in high-drain situations.

Fusing, breakers, relays: Useful items for boats frequently can be found in the railroad department of a hobby shop, or at an electronics store. The clerk may ask you what voltage and current you are working

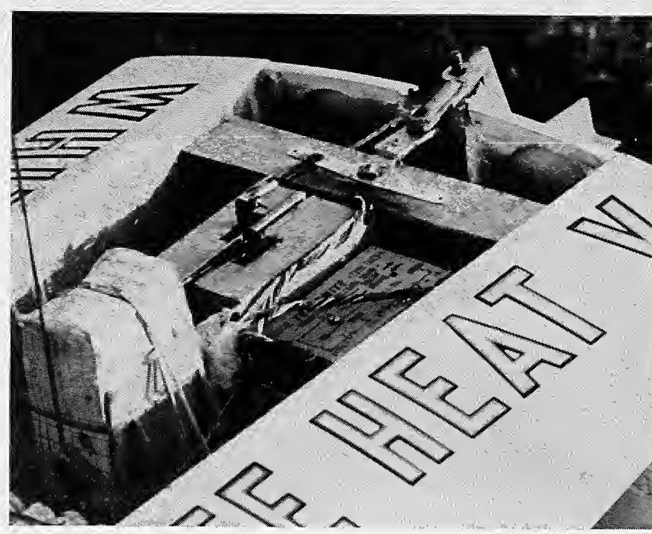


An excellent example of a radio system in a small 14″ plastic converted-toy boat. The use of chokes and arc suppressor points up the importance of eliminating electrical "noise" which interferes with receiver operation.



This is the circuitry for the installation shown in the photo above. Batteries are nickel-cadmium button cells.

7-14 **Close-up of modified airplane servo (wired for proportional action with appropriate transmitter) with nylon gear train and adequately rated "pot" to vary voltage (approximately several amps. stalled current) to drive motor.**



Installation of radio and servos in a racing hydroplane. The receiver is packed in a waterproof bag and wrapped with a protective foam rubber padding.

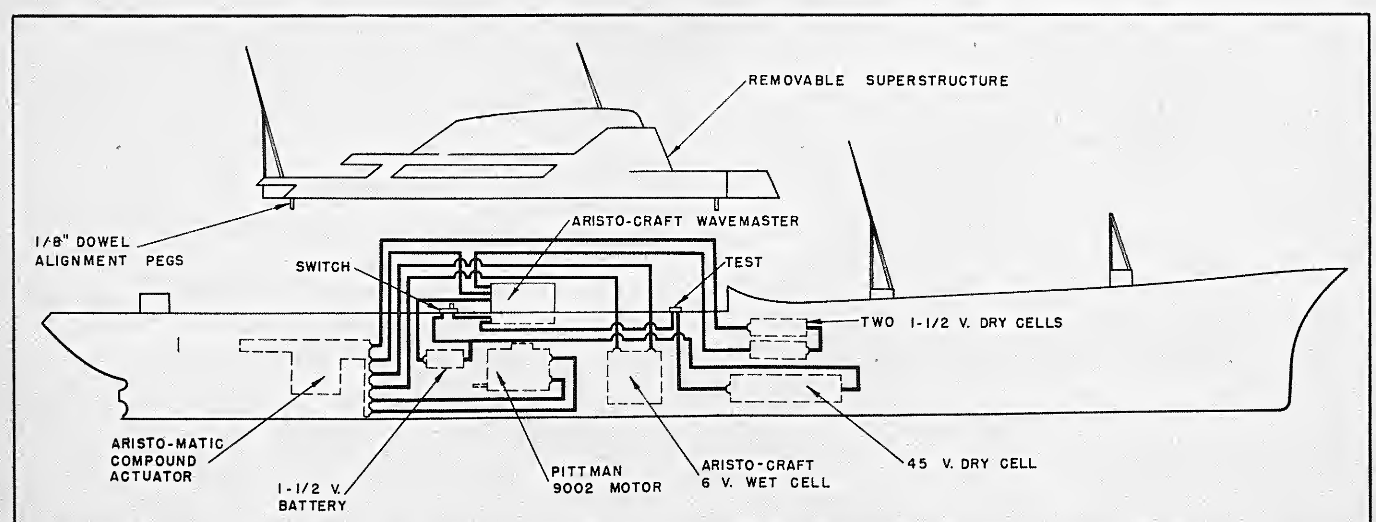
with, in order to give you the properly rated parts. Relays always are designed for specific voltages and currents, a fact many hobbyists don't appreciate. Relay contacts, in this instance, should be capable of handling from 3 to 6 amperes (to play safe). To illustrate, two Decaperm motors will pull 2 to 2¼ amperes. Four- and 5-ampere loads are commonplace. This is where a fuse or circuit breaker can save equipment. Fuses, or breakers, should be obtained which will blow, or open, when excessive drain is reached, and power cabling should be of a sufficient-gauge wire to take overload currents. (If wiring heats or feels warm, add parallel wires between the same connections.) Use adequate switches in high-current situations — rated to 125 or 230 volts. To avoid overloading one set of contacts, double-throw relays are suggested; this divides the load between two sets of contacts.

Importance of "noise" suppression: Electronic noise (spurious, random emissions) is a far greater problem in a boat than it is in an airplane, especially with electric drive — drive motors pull far more current than a servo motor, and there is much more arcing of brushes, etc. When voltage is increased, noise problems become more likely and "arc suppression" is increasingly difficult. Various actuating devices and switching devices with make-and-break contacts introduce effects that interfere with radio reception or receiver stability. Compact installations, unless carefully handled, may bring systems components into close proximity, with accompanying noise interaction. Gas engines that severely rattle metal linkages, hardware, etc., create noise. In spark ignition, there may be interaction with some receivers. Noise comes from many sources.

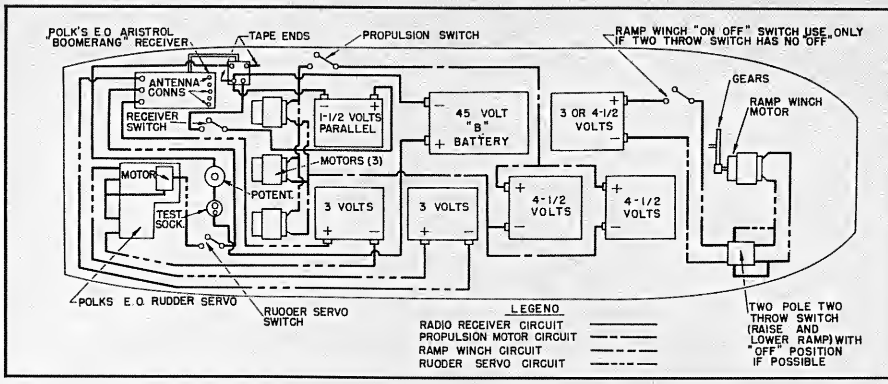
We have mentioned the importance of keeping the receiver away from electric motors, and its antenna free of installed equipment and power cables. In general, two measures will control most noise sources:

- Suppress any device that creates sparking, by installing appropriate resistors and condensers, or diodes, across electric motor wiring terminals; across any servo or gadget motor which is not suppressed by the manufacturer; across all make-and-break contacts on relays, switches, etc. When the magnetic field of an actuator coil collapses, as one example, the resulting spark discharge can introduce a voltage spike in the hundreds of volts — enough to burn out a condenser of an inadequate rating.
- Avoid metal-to-metal linkages by the use of nylon clevises, bell cranks, control horns, etc.

For relay contacts which carry considerable current, an appropriate resistor and condenser (such as 10-ohm



Schematic for model of Savannah atomic-powered ship. Both the LST (page 55) and the Savannah were built by Walter Musciano.



Schematic for the LST (page 55) indicates possible versatility of single-channel systems and suggests approximate layout of physical system components in such a hull.

½-watt carbon resistor and .01-mfd. ceramic condenser) can be wired in series and connected between the relay frame and contact. If both contacts are employed, "suppression" is duplicated. When actuator voltage is cut off, there is a collapse of the magnetic field which causes a spark discharge across relay contacts; suppression restricts this. Most modern receiver equipment now incorporates proper suppression.

Interference effects of the electrical "noise" of motor brushes running on a commutator usually is taken care of on servos by factory installation of an appropriate resistor across the terminals.

The values of resistors and/or condensers to reduce motor arcing vary with voltage and amperage and may have to be found by trial and error. If the manufacturer of the motor does not give this information, write him for advice. An example of a motorized actuator which reverses polarity would be (in series) a 10-ohm resistor with two 1-mfd. 50-volt subminiature electrolytic capacitors wired back to back (plus to plus), the whole connected between the motor terminals. For higher drain, a 10- to 20-ohm ½-watt resistor, or two diodes (100- to 200-volt PIV) back to back, is one example.

What control system? In the smallest, simplest boat, rudder-only control might be acceptable, but once the novelty wore off, such a boat would not be rewarding. So the simplest controls that can be considered practical include left and right rudder, plus motor forward, stop-start, reverse — or a throttle for a gas engine. To this minimum can be added various auxiliary control functions and/or half-throttle positions for the electric motor — all this with single-channel radio by means of actuators or switches on the market. Greater flexibility and capability can be had by using multichannel radio.

Single-channel: Escapements are so limited — they lack muscle for water operation — that we need not consider them. Two methods are popular for moving the rudder: (1) an actuator such as the Boatomatic and (2) pulse proportional (more limited). In the former case, the rudder can be moved to right or left full positions by holding a signal, or the second of two signals; other functions are available through a quick-blip sequence which closes special contacts, as for the electric drive motor (forward, start-stop, reverse) and special services (horns, lights, etc.). However, it may be desirable to use relays — more than 2 amperes drain — in the drive motor circuit to avoid burning up the actuator contacts. In the case of proportional the usual actuators can be used, the airplane-type wagging rudder not being evident since water dampens out action.

Much depends on the speed of the boat, because faster boats are not too easily controlled by devices which give relatively slow-moving all or nothing positions of the rudder. Also, as control surface loads build up with speed, more powerful actuators are desirable. One single-channel system answering both problems is proportional with a feedback servo suitably geared.

In the pulse systems, a pulse-omission-circuit-detector with the receiver is used for operating a motor control actuator. Also, a number of airplane-type actuators, useful for boats as well, include mechanical means of advancing and retarding the motor control — which can be either a pot (Fig. 7-14) to vary motor voltage, or a throttle in the case of a gas engine — with the pulse systems. The Marcy PRM-1 system has a second motor-control servo which is selectively positionable.

In addition to sequence switchers the reader will think of many other possibilities, such as sliding resistors —but is reminded that noise interference possibilities are increased.

Receiver limitations: In single-channel the transistors in a relayless receiver will not carry the high-drain loads — notably, any direct circuit to a drive motor. A relay circuit should be added, or a relay-type receiver should be used. In relayless multi, the servos contain their own transistor amplifiers designed for any actuating loads, as the servo motor itself, through its gearing, is adequate. But if any channel of the receiver is directly used, for sequencing, etc., a relay should be inserted — the relay thus is the switch for an independent electrical circuit.

Multichannel: The advantages are selectively available controls, more controls, more precise and finer control of all functions, and adequate output power. By modifying a servo — using special gearing if necessary — a potentiometer can be turned, varying resistance in a circuit and thus controlling a high-drain electric drive without the drive motor circuit passing through the receiver or, say, a switcher with contacts that are too light. Or a servo can operate a slide resistor, followed by a transistor amplifying circuit, then relays — again for drive motor control. A single-channel servo, such as Citizen-Ship, can be employed to operate a double-throw switch, thus selecting between circuits (perhaps between relays for independently supplied circuits) for such things as stop-start, forward and reverse.

The possible arrangements with multi are limitless. However, the most common installations require at least four channels. Here, two channels would be applied for right and left rudder on a single servo, and two more on a motor control servo, with one speed forward, stop, and one speed reverse (if electric). By a minor change in the wiring of these servos, a trim or positional action is available. For the rudder, positionable is suitable if running speed is not high — there is no automatic neutral and the operator must search for neutral. Advantage of positionable motor control is a full variation in forward and reverse speeds.

Response time is another advantage of multi servos. Quick reaction, plus selective controls, helps avoid obstacles at high speed and improves maneuverability. Multi servos are the same for either airplanes or boats.

If more than four channels, other channels can be used to operate special functions directly, one per servo. Or switching devices placed in one or more of the "extra" channels can multiply available operations to a remarkable degree.

Multiproportional radio would provide for at least three primary functions with fully proportional response.

8: AIRPLANE INSTALLATIONS

MOST control difficulties stem from badly handled installations rather than from radio. A poor installation has a confused organization, and lacks neatness.

Compared to other kinds of radio models, airplane installations are standardized. Space usually is at a premium. Distribution of weight is extremely critical. In the typical compact installation (Fig. 8-1) elements of the system are strung out in a straight line — batteries forward, followed by the receiver and then the actuator or actuators.

Figs. 8-2 and 8-3 display arrangements for single-channel and multi-channel craft. All parts of the system require easy accessibility.

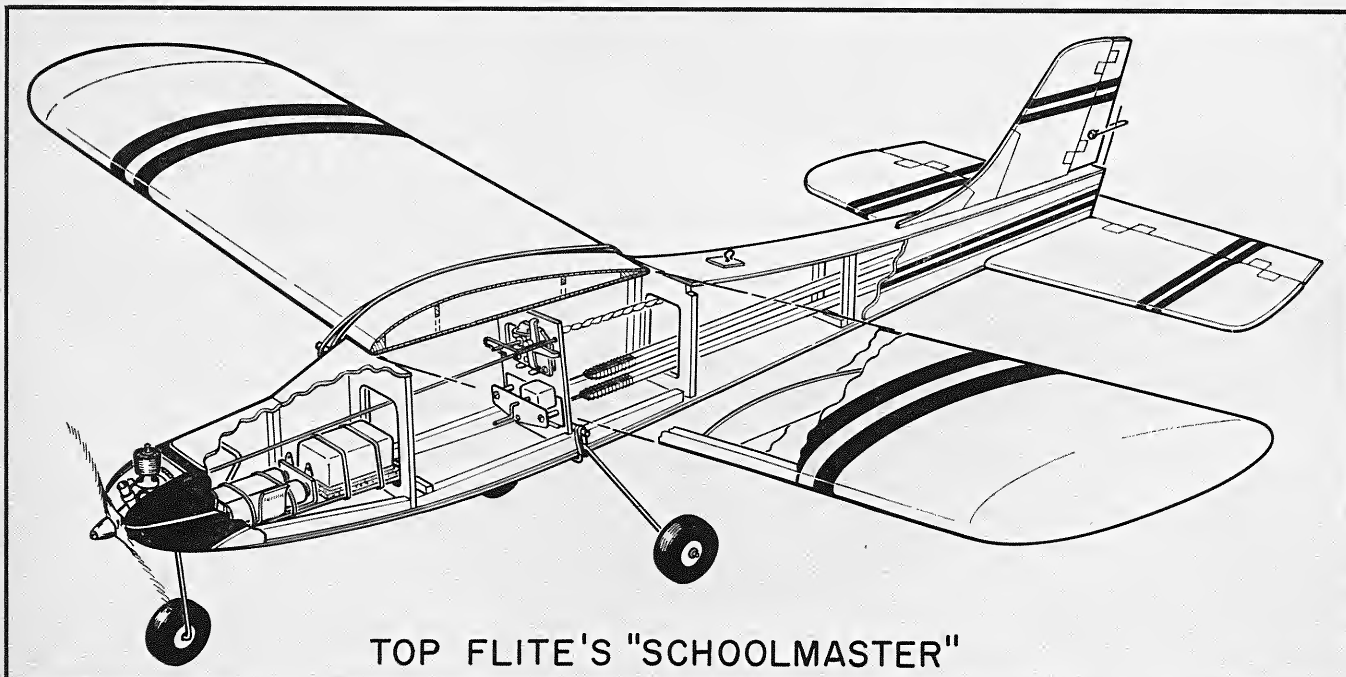
Battery location: In most cases the batteries locate in the nose, forward of the wing leading edge — a position dictated by the need to balance the plane at a required center-of-gravity position. In this forward position the batteries do not endanger other equipment in a crash. (Fig. 8-4.) Access to the battery compartment is by a removable nose hatch, or from the cabin through an access hole cut in the front cabin bulkhead.

Occasionally batteries are placed aft of the front cabin bulkhead, but forward of the receiver. This requires reinforcement of the bulkhead (except on small models) to prevent the batteries from moving forward should the craft nose into the ground.

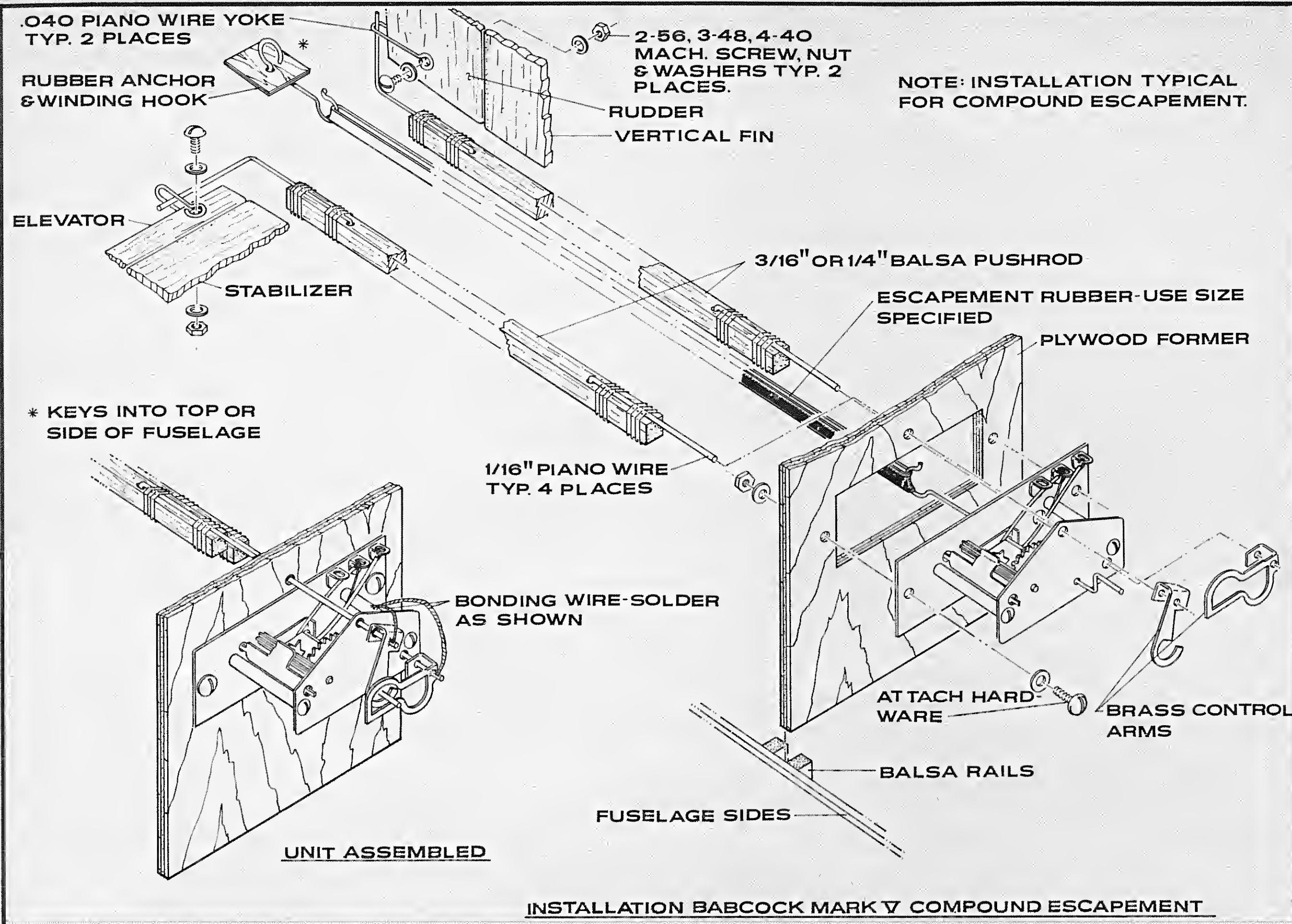
Pack or box? Two schools of thought exist for battery installation when a commercial nickel-cadmium pack is not used. One favors the battery box, which may be removable or stowable, or permanently attached to structure, the batteries being quickly removable from the box, which holds them tightly clamped. The other favors the battery pack, which conveniently groups the batteries tightly wrapped with plastic electrical tape. (Fig. 8-5.) Leads are soldered to the batteries. When removable, either pack or box is wrapped in foam rubber and is wedged into a compartment or nose space. Rechargeable nickel-cadmium batteries make the most practical packs, since they can be left in place for the life of the airplane. (Fig. 8-6.) Dry cells require more or less frequent replacement.

Various plastic battery boxes with slide-off lids — such as Du Bro's — accommodate different combinations of penlight size batteries (and others) which can be either rechargeable or dry-cell types. Such a box packages the batteries in an arrangement which can be equated with the taped-together homemade packs. Metal battery holders are available in many sizes.

The pack and rechargeable batteries nowadays are almost synonymous. Mixed combinations — such as escapement, filament and B batteries — are less commonly seen because of transistorized and relayless equipment. Disadvantages of the pack are these: Leads must be soldered to the batteries; if the ampere-hour or milliampere-hour capacity of the pack is limited, as it can be in certain sizes of planes due to weight, the number of flights will be limited per session unless a replacement pack is available. This requires a plug-in connection, with a similar plug on each pack.



8-1 **A versatile single-channel installation by Ken Willard. The lower escapement is a Babcock compound; a Bonner SN is used as an auxiliary for engine throttle control. Batteries and receiver are placed forward for balancing.**



8-2

Soldering the pack: Terminals must be cleaned (with fine sandpaper), then tinned so that the connection can be made quickly to prevent heat damage. An iron of at least 37 ohms resistance is recommended. Instructions with some nickel-cadmium cells, especially the button type, recommend against soldering, although many people do so without trouble. (Nickel-cadmium batteries also come in penlight sizes, etc.) Many button cells have soldering tabs; some do not. Some are obtainable in convenient packages consisting of two or more cells (of various ah.-mah. capacities). If you make your own combinations of these cells, disks of thin plywood or cardboard can be used as separators where an electrical connection is not desirable. A tight wrapping with plastic electrical tape will hold the cells tightly together in a pile. The leads from the pack should be doubled back under the first layer of tape, then taped over, preventing wire fatigue at the battery connection. When batteries have metal ends that do not readily take solder, either a box should be used or a part of the paper wrapping should be removed when the case has the proper polarity, and the lead should be soldered to the case.

The battery box: The metal type should be rigid, never made from thin or easily bent metal which can lose contact pressure. Loose-fitting batteries involve voltage drop and interruption of current with vibration; and they create electrical noise that can disturb a receiver.

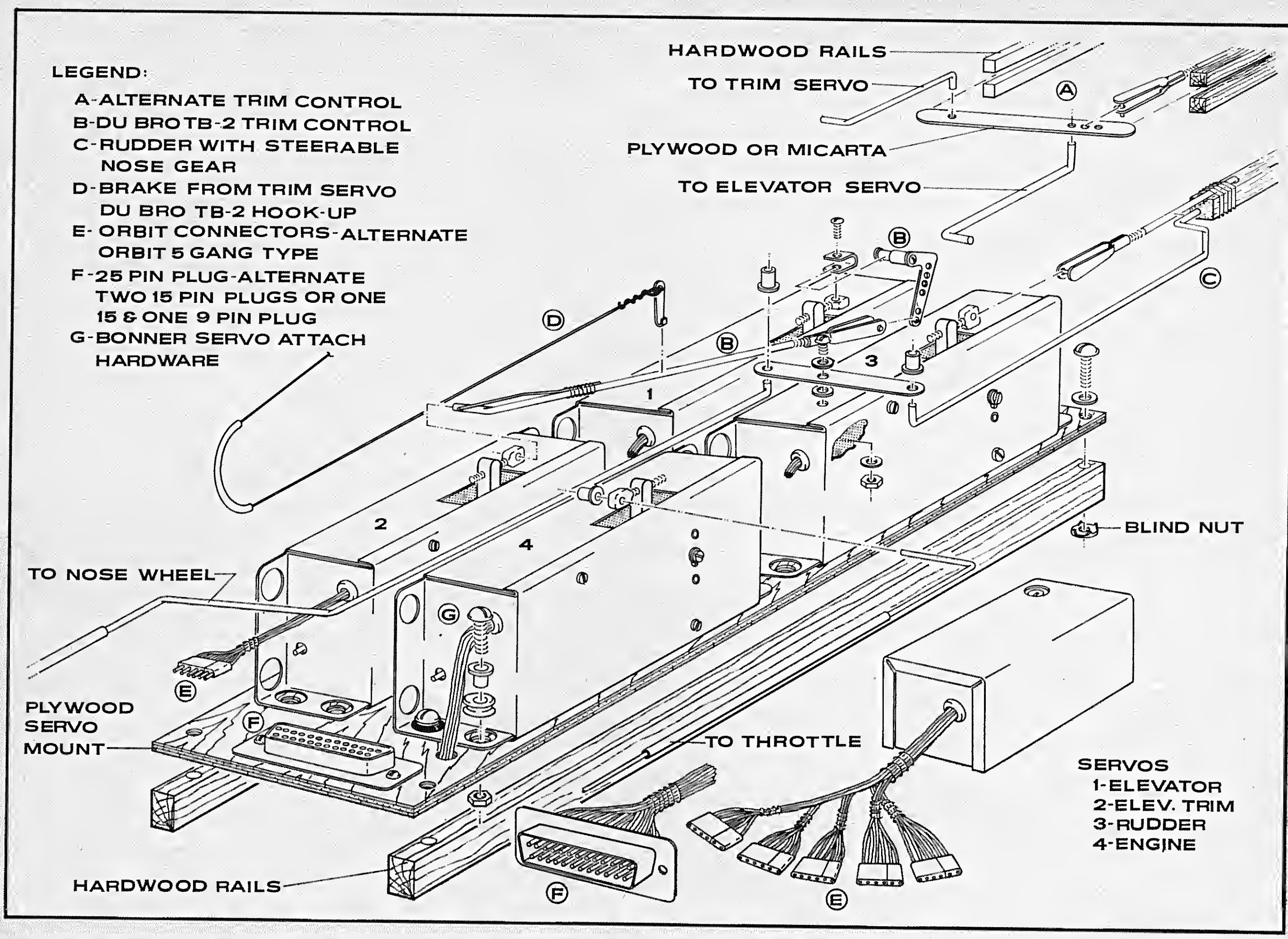
When the box is rigidly mounted, wire leads should be anchored to prevent breakage at the box, caused by handling and/or vibration. If the box is stowable, like a pack, the leads should be long enough to allow doubling them back along the box in such manner that a rubber band holding them to the box prevents wire breakage. If there is doubt about the contact pressure provided by the open metal box, wrap the box tightly with a rubber band to force its ends more tightly against the battery terminals.

Receiver: Mounting should be "soft" to minimize vibration effects, especially in types which have tubes, relays or reed banks. This soft mounting also serves to protect the receiver in a crash. Any receiver which is enclosed in a can or plastic box can be wrapped with a layer of thin foam rubber (Fig. 8-7), held by a rubber band, then placed in a compartment which holds it snugly (but not a jam fit). Multichannel receivers almost always are so installed, but single-channel units — which includes those not housed in box or can — often are mounted on a piece of foam rubber (by contact cement), which in turn attaches to a thin plywood tray; the tray slides in channel strips glued against the fuselage sides, or against the front cabin bulkhead. (Fig. 8-8.)

Contact cement should not be used over exposed printed circuitry on the bottom of a receiver chassis. The circuitry can be protected first by several coats of model airplane cement. Receivers also can be nested in a pocket comprised of foam rubber slabs. Ordinarily, foam ¼" to ½" thick suffices for all wrapping purposes.

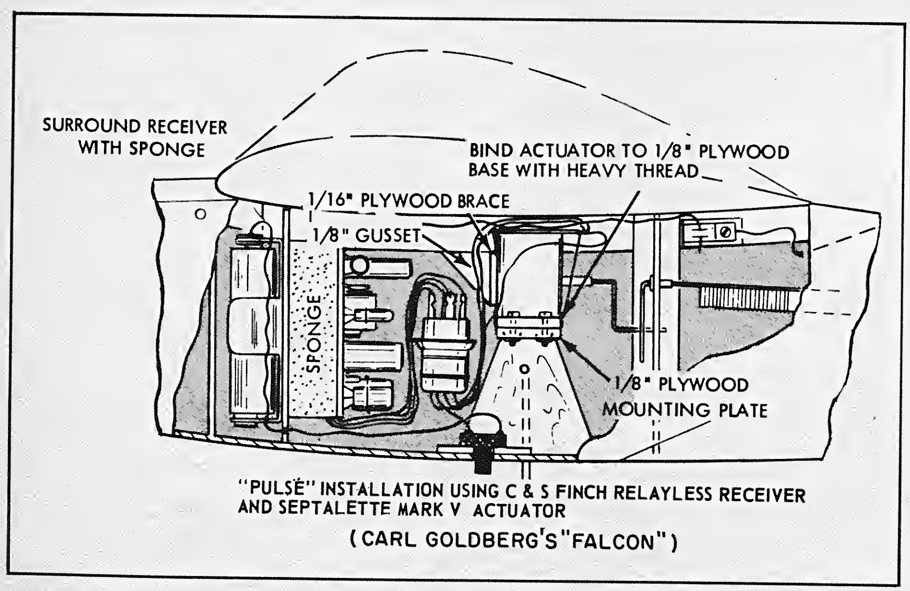
Receiver location: The receiver should never be placed forward of batteries and, when possible, not directly in front of heavy actuators which can break loose in an accident. Properly installed, a receiver can withstand unharmed an accident that totally destroys the aircraft.

Receiver placement can have important effects on the functioning of the entire system. Tight packing asks for trouble. Not only can engine vibration cause unwanted control actions due to accidental operation of reeds or relays, but even when such vulnerable items are not present, in-



8-3 Typical multicontrol servo installation. Servos bolt to ply platform which bolts to hardwood runners in fuselage. Lower right: Receiver servo connections can use either a large multipin connector or a number of smaller individual connectors.

terference-type effects (random electrical "noise") can sometimes be noted. If the radio has relays and/or reed banks, the receiver should be so positioned that the relay armatures, or reeds, do not lie in a plane horizontal to the direction of movement of the engine's piston. Thus, with an upright engine, the reeds should point downward. Many installations do not suffer these vibration effects, but proper receiver positioning is the cure if the trouble appears — and good practice in any case.



8-4 Typical magnetic actuator (pulse, proportional, single-channel) mounted in Falcon Jr. Actuator should be secured against movement in crash to protect receiver.

Actuators: In single-channel, common practice is to permanently install the actuator, whether it be an escapement, magnetic (pulse), motor-driven (pulse), or some special type. In multichannel, servos are generally grouped on a removable plywood platform which allows for the inevitable maintenance required; however, in proportional multi, servos also can be mounted singly, on fuselage bottom or sides.

Most popular single-channel actuator is the escapement. Although action is transmitted to the rudder by either a pushrod or a torque rod, the latter now is almost universally used. (Fig. 8-9.) Details appear on almost every appropriate kit plan or on the escapement's direction sheet. Specifications — measurements, wire sizes — should never be departed from, because the degree of rudder action will be changed and undersized steel wire linkages may permit control surface blowback. The reason for permanent mounting of escapements is that in most cases the torque rod and its fittings use the escapement frame for a bearing, and cam follower and other drive arms soldered to the wire end of the torque rod tie in the es-

capement. Even so, it is advisable to provide for removal of the escapement for adjustments which may become necessary. This is done by mounting the escapement upon a plywood frame (3/32" to 1/8" thick) which in turn slides into wood channels on the fuselage sides; a spot of cement prevents this plywood from accidentally shifting. Should servicing be required, an escapement that is glued into the fuselage presents a problem.

Some escapements have moving parts or shaft ends which project through holes in the back plate; be sure that the ply mount does not press upon these parts (cut away if it does). An escapement, unlike a powerful servo, is highly susceptible to artificial drag imposed by poor alignment with torque rod and rubber, or by restriction of moving parts.

Accessibility for inspection and troubleshooting, replacement of rubber, etc., is important; therefore the escapement should be located far enough forward in the cabin that the rubber hook can be seen through the open cabin top. (Fig. 8-10.)

A common mistake when installing the torque rod is to provide too much end play (which allows a cam follower to jump the cam on a Vari-Comp, for example) or insufficient end play, which creates enough drag to throw off your timing of control signals. Normally, a small washer or bushing is soldered on the aft-wire-end of the torque rod behind the fuselage stern post; when soldering this washer, place a 1/32" thick balsa shim between washer and post; then remove the shim. The bearing through the stern post should be a snug-fitting (but not tight) bushing, or a Micarta or metal strip.

Kickup escapements: A number of escapements operate a second torque rod when the appropriate signal is held. The second rod then tips up an elevator. (See Fig. 8-11.)

Motor control escapements: These are the self-neutralizing type; they operate when a circuit is closed by a switching contact on the primary escapement. Location is always a problem, since most throttles have a push-pull motion which militates against mounting the engine-control escapement in similar manner to the primary escapement. Usually, the MC escapement must be mounted (see Fig. 8-10) with its rubber hook pointed downward, and the rubber stretched between the hook and a plug in the cabin floor. Very often the rubber length is severely restricted in small planes. Normal location of this auxiliary escapement is between the receiver and the primary actuator, high on a cabin side. Usually, a great deal of trial-and-error fitting is necessary to obtain the throttle movement required for suitable low motor operation. Push-pull operation of a throttle would require a bellcrank arrangement. (Fig. 8-12.)

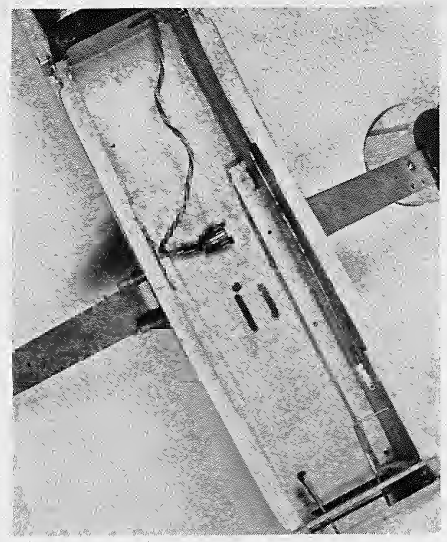
Servos: In most multi designs the fuselage width is determined by the required size of the servo mounting board, which attaches to two hardwood bearers by means of either 3-48 or 4-40 blind nuts and bolts (a hobby shop item). Thus, by removing the four hold-down bolts in the corners of the board, the entire fuselage servo installation lifts out, either through the open fuselage top on a cabin or shoulder wing, or an open bottom in the low wing. Quick-detach fittings on all pushrods facilitate disconnecting the pushrods.

The plywood tray may be either 3/32" or 1/8" thick. Printed circuit mounting boards are obtainable; servo leads solder directly to these. These printed-circuit tie-boards can install with the servos that attach to the ordinary ply mounting, or may even replace the plywood board. Servos have a rubber-grommeted mounting hole, and bolts should not be tightened sufficiently to squash the grommets. Hardwood mounting rails should glue to fuselage sides or bottom in a fore-and-aft direction. Cross-mounted bearers tear free too easily.

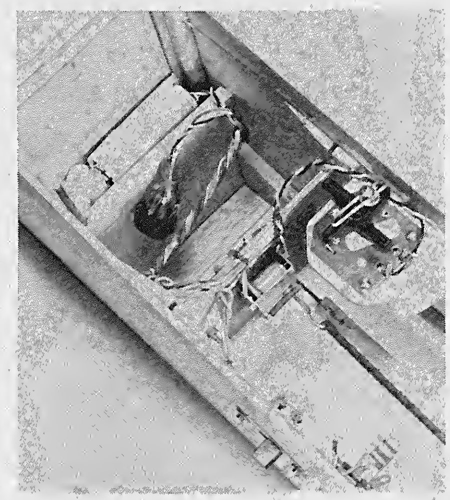
The servo board can be the focal point for radio, battery and aileron servo connections (the latter servo being in the wing center section). Sockets in the plywood mount take plugs for all three purposes. Ordinary plugs and sockets are not recommended; these items should be of some dependable, high-quality type such as Winchester — or, where possible, use multipin connectors. These come in many brands in both the hobby and the electronics industries, and with as many pins as desired (to the many dozens). Printed-circuit junction boards, and various junction plugs designed especially for multi, are available. If the switch is mounted through the board it will be accessible through a slot in the fuselage bottom — but should not project to strike the ground if the detachable landing gear is knocked out of place. This switch location removes all fixed wiring from the airplane structure proper — always a potential failure point. (Fig. 8-13 illustrates a complete 10-channel servo setup.)

When necessary to mount servos on fuselage sides, the inside of the cabin is reinforced by 1/16" plywood pieces attached to the sides with contact cement. Blind nuts accept the short mounting bolts. Fig. 8-14 shows Annco servos mounted in a very small multi "compact."

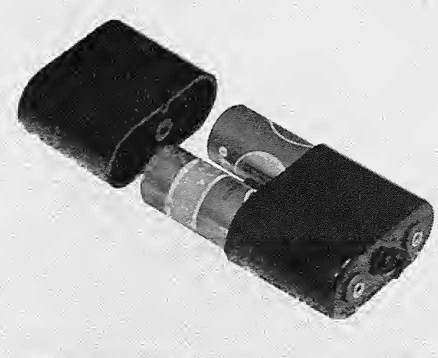
Actually, servo installations can dif-



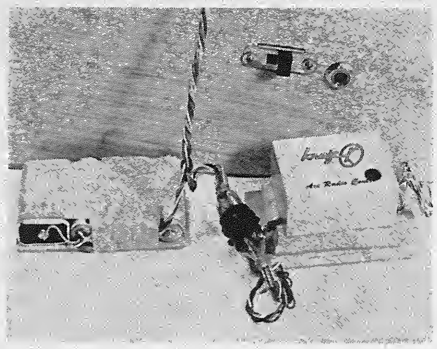
Dyna Soar multicontrol fuselage, equipment removed. Note hardwood servo tray bearers in bottom corners. Slots in bottom pass switch handles (switches on servo tray) when equipment is inserted. Socket and cable connect to nickel-cadmium battery pack buried in nose compartment.



Batteries are in the cabin in this single-channel installation using Vari-Comp compound escapement (across cabin) and Bonner SN escapement for throttle actuation. Note how all wires are cabled and fastened down where feasible.



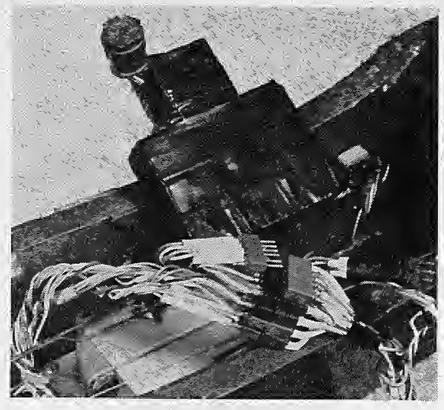
Plastic and metal boxes are available for all kinds and sizes, and combinations of batteries. Picture shows small Du Bro box for two penlight batteries.



8-5 Battery pack for .15-size plane with tube single-channel receiver includes B battery and four penlight cells. Note receiver on foam-rubber slide mount.

fer in many ways. Typical recommended methods are illustrated, including the aileron servo in the wing. Influencing factors include the routing of the flexible pushrod to the throttle, attachment of nose-wheel steering pushrods or cords, and whether standard or strip ailerons are employed (in turn affected by whether the wing is on top or on the bottom of the fuselage). Detailed arrangements conform to individual airplane configuration, whether it has a two- or three-wheel landing gear, etc.

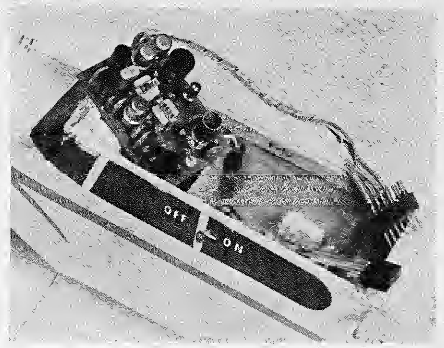
Hinges and fittings: There are at least five types of hinging: U-control pinking-tape hinges; metal tube and steel wire (1/32" to 1/16") with the tubing pieces attached to the structure with pinking tape; manufactured metal hinges; nylon strip hinges; and nylon thread sewn figure-8 through the control surface and airframe. Aileron hinging is particularly critical because airloads, vibration and flutter are too much for cloth hinges or any



8-6 Taped nickel-cadmium battery pack for 10-channel installation. Socket accepts either receiver cable plug or plug from charger. In foreground, individual servo connectors are epoxied side by side (with thin plywood separators). Projection on battery pack is power converter to supply both A and B voltage to tube receiver.

hinge that cannot be securely anchored. When in doubt, the figure-8 stitching always will suffice.

Bell cranks, control horns and other allied parts are obtainable in finished form at the hobby shop, and they come in numerous variations. Illustrated instructions are quite clear. Pushrods, etc., can be inserted into servo drive arms or bell cranks and horn by following U-control practice of bending at right angles the end of the wire (which is thread-wrapped and glued to the wood pushrod). A thin steel wire "keeper" prevents the bent-over pushrod wire from sliding out of the hole. However, most multi builders prefer the manufactured Kwik Link thread-adjustable pushrod attachment. (Fig. 8-15.)

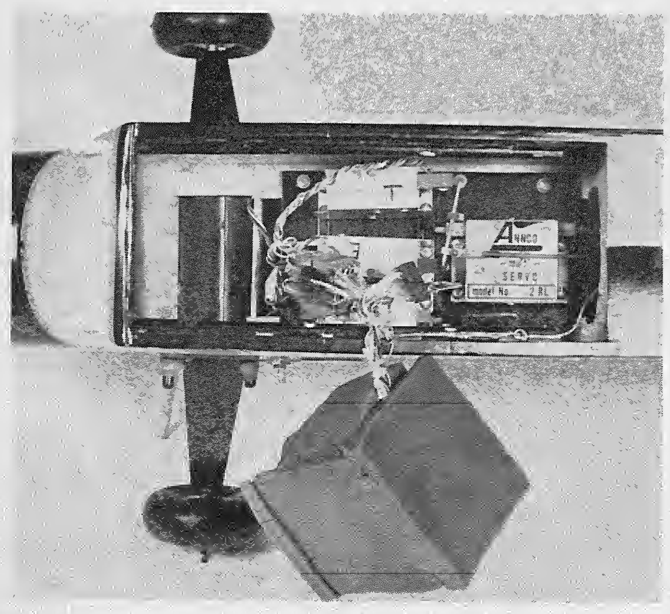


Tiny transistorized relayless receiver in a Lightning Bug. When receiver cable is disconnected, plug from charger inserts. Uses a 225-mah.-sized nickel-cadmium pack.

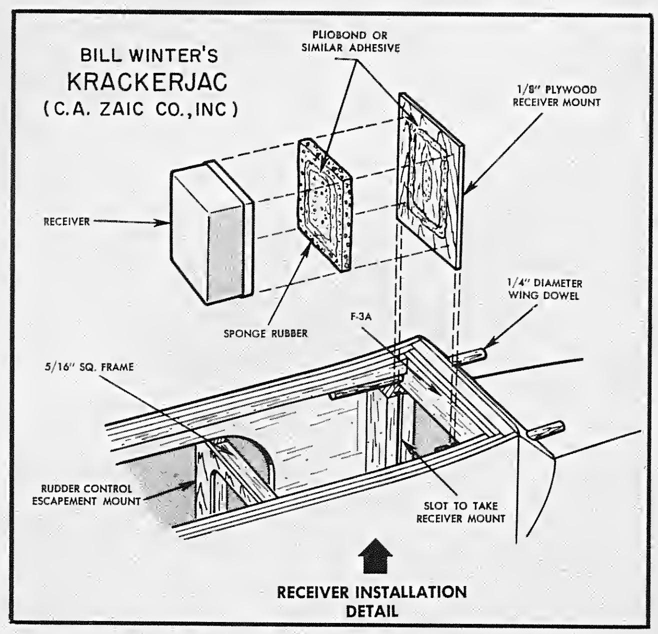
Aileron linkages: Illustrations show two basic types. For the standard-aileron type, a wire pushrod extends from one aileron bell crank to the other bell crank in the opposite wing panel, attaching to the aileron servo in the center section. Other, shorter, wire pushrods extend from each bell crank back to the aileron horns, which may be on top or on the bottom of the aileron. Plywood disks or metal bushings can be inserted through some ribs to prevent bowing of the main pushrod.

With strip or full-span ailerons, the horn can be at or near to the root of the aileron, with a short pushrod extending back from the servo to the horn, avoiding the more complex internal installation required for the standard aileron. Strip ailerons, which make the wing simpler to construct, are increasingly popular, especially for multi proportional setups.

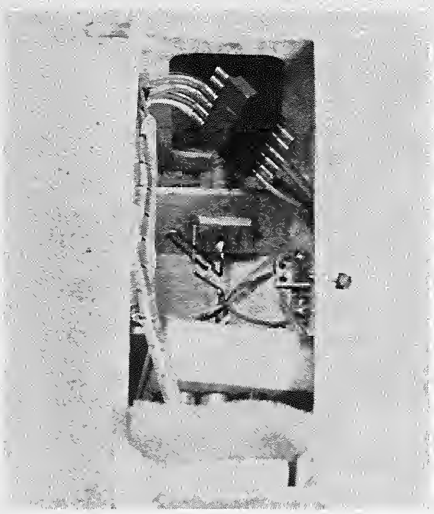
With standard ailerons—which present extra air drag in the down posi-



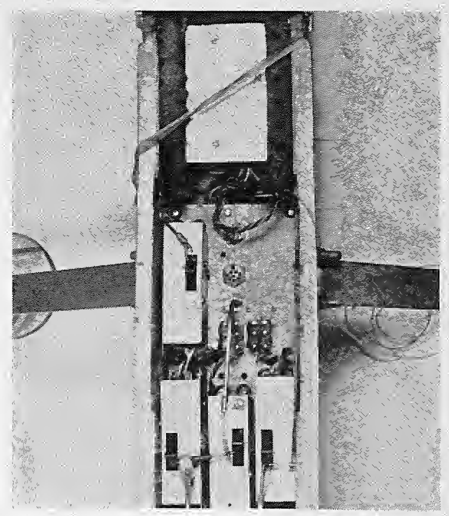
8-7 Multichannel receiver in foam-rubber protection. Medco nickel-cadmium battery pack just above landing gear. Four Annco servos for all controls but aileron in DMECO Aeronca.



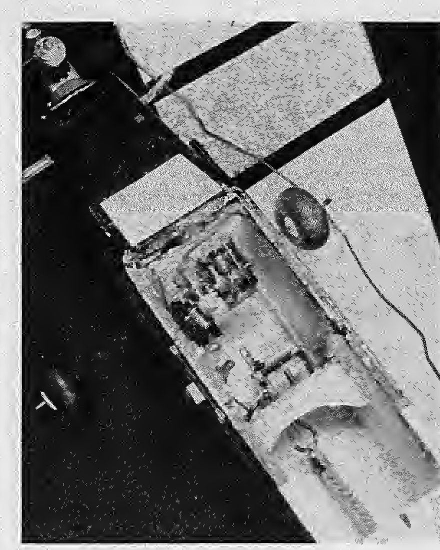
8-8 Single-channel receiver on sliding tray is quickly removable and protected from forward movement in crash.



Cabin of .01-powered model, showing torque rod (for rudder control) yoke for use with Septalette actuator (actuator arm visible). Note subminiature Otarion switch at right.



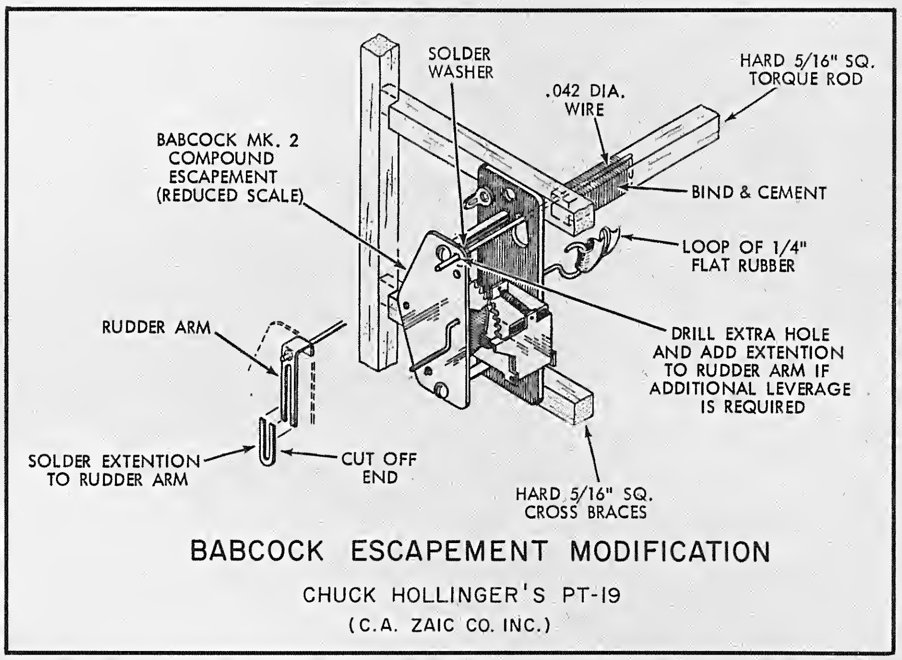
Same fuselage as in top photo, page 71, but with servo board and receiver in place. Tube conduit to center servo carries the brake actuation cord.



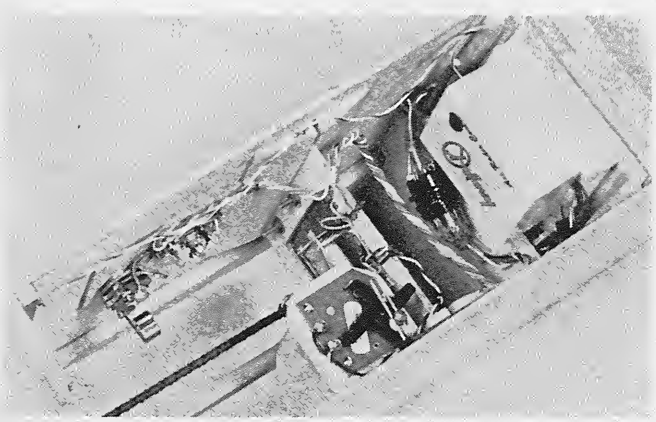
8-9 Tiny Citizen-Ship transistorized relayless receiver and self-neutralizing escapement in Lightning Bug.

tion, causing yawing of the machine — a differential action (more up than down) is imparted by offset aileron bell cranks, or by shifting the aileron control horn position relative to the hinge line of that control surface (to the rear of the hinge line when the horn is under the aileron).

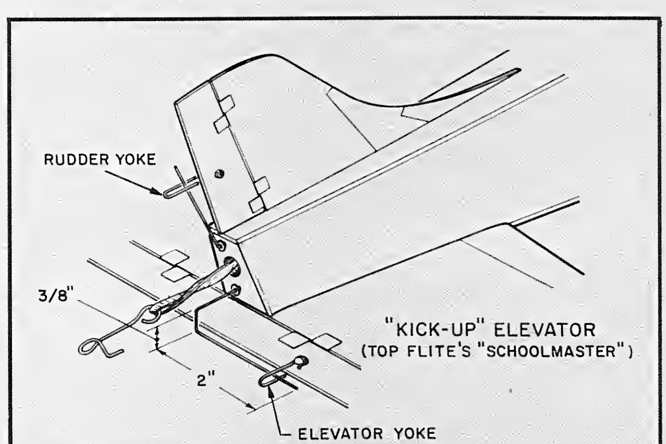
Steering: In the "trike" gear, the steerable nose-wheel shock-absorbing strut rotates in a nylon or metal mounting bracket which bolts to a strong plywood bulkhead. An arm attached to the strut is connected (by pushrod, wire or monofilament fishing line) to the rudder servo. The system is arranged to give less angle of travel for the nose-wheel steering than for the airplane rudder, usually 1 to 2. Depending on the servo position relative to the nose wheel, various bellcrank arrangements, metal tubing conduits, etc., transfer motion from servo to the strut. (Fig. 8-16.) Shock which ordinarily would be transmitted directly to the servo is partially absorbed by such devices as dogleg



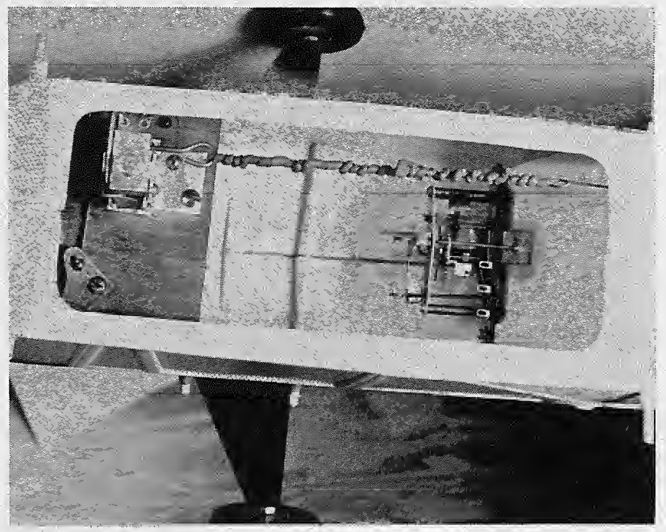
Interesting escapement modification for the purpose of increasing power to move larger control surface.



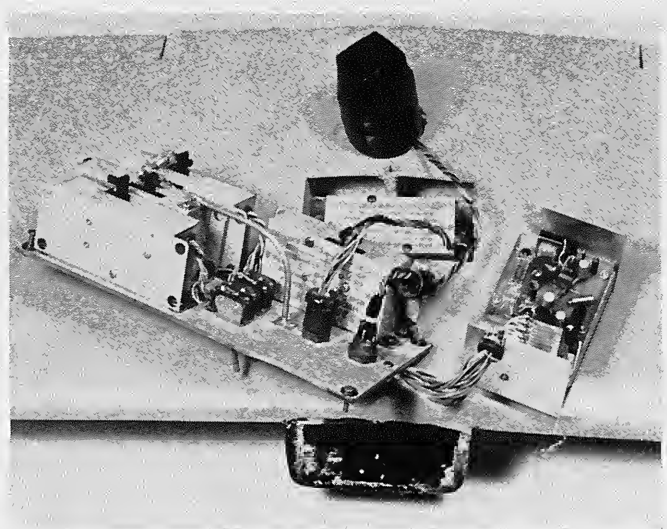
8-10 Another view of installation in center photo, page 71, with receiver in position. Shows complete wiring, including knife-action slide switch and phono jack (for meter).



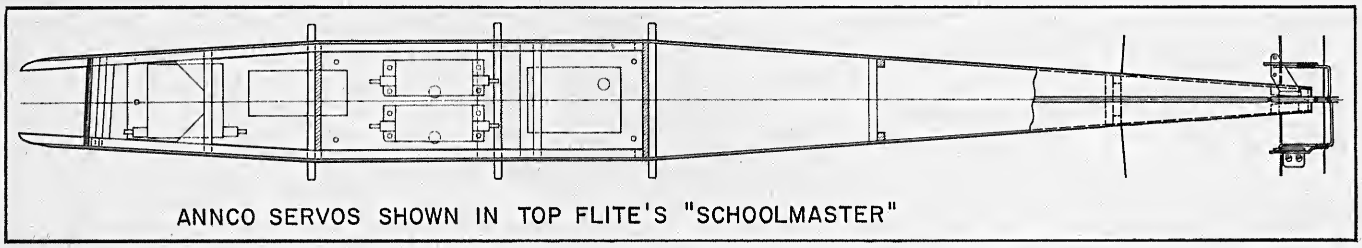
8-11



8-12 Motor control escapement (left) in this .049 rudder-only model actuates throttle via bell crank, solving problem of transition from rotary movement to linear movement. Compound escapement at right.



8-13 Complete 10-channel system, including aileron servo in wing. Battery pack at top; receiver, right, cover off. Note how aileron servo and battery power plugs insert into sockets on servo board. Receiver is wired in — no plug and socket.



8-14

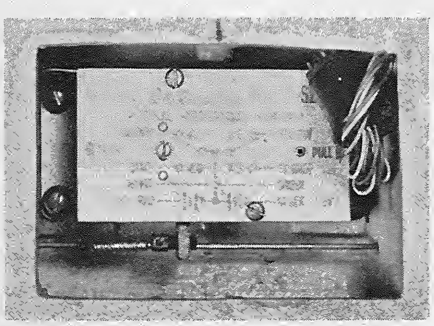
bends in wire pushrods or coil springs in monofilament lines.

In two-wheel ships, steering is achieved by a swiveling tail-wheel action, actuated directly by the rudder. Drawings in chapter 4 show braking and steering details of a three-wheel gear.

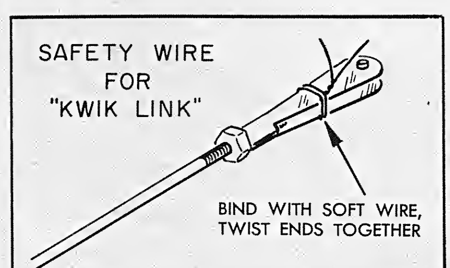
Wiring harness: The word harness implies that the wires should be grouped into a cable, tied together as shown in Fig. 8-17. The harness can be assembled outside the airplane. For single-channel and other simple machines, the harness is dropped into place, running along the fuselage sides or bottom, and up bulkheads, where they glue to fuselage sides. Soldered connections to escapements, etc., that are already in place are made last. For attachment to switches, jacks, etc., the wire ends can be drawn through the holes made for those objects, and can be soldered as required; and then the switch or jack can be inserted permanently in place. In multi, the cable lifts out with the installation, with the wiring system separating, when necessary, by means of multipin connectors. Switches are removable with the harness.

The proper wire lengths can be measured for making the harness by measuring the runs inside the fuselage and allowing for some slack. Wires should never be tightly stretched. Pictures throughout this chapter show methods of securing wires to switches, sockets, plugs, terminals. Fatigue of all soldered wires must be guarded against. Do not allow solder to flow far up the wire, because the wire will break at the end of the solder which, in effect, has converted the wire into a single strand. Most commonly used wire is No. 26 with 19 strands. Figs. 8-18, 8-19 and 8-20 show generalized schematics.

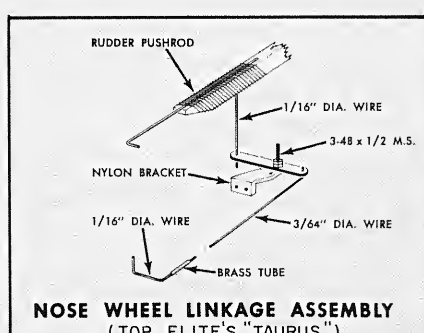
The power plant: There are two basic types of engine mountings: *radial* and *beam*. Some engines can be mounted only radially (these in the small sizes); others only lug-mounted on bearers (standard in multi); and some provide for either method. As a rule of thumb, radial mountings are



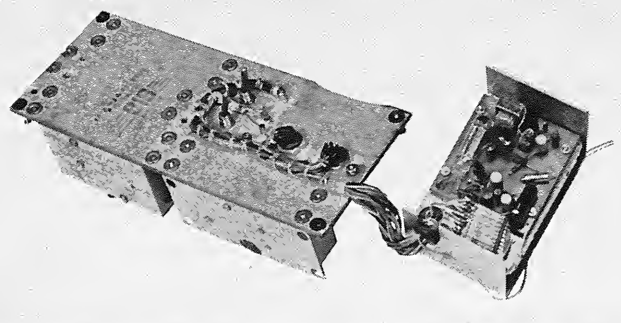
Standard aileron installation in wing which uses conventional ailerons (not strip ailerons). Pushrod extends through ribs on either side, out to aileron bell cranks. Power cable plugs into fuselage system.



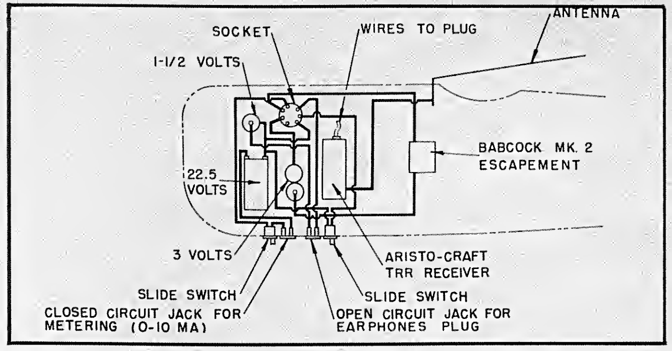
8-15



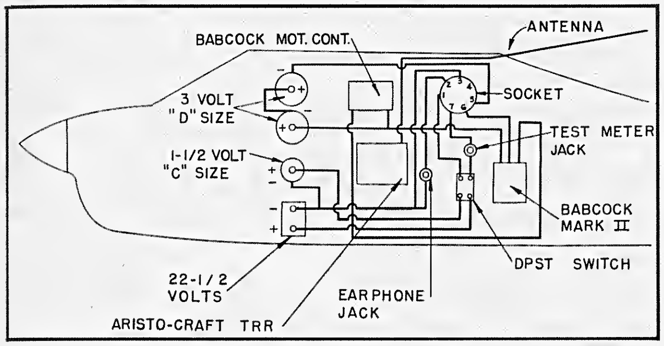
8-16



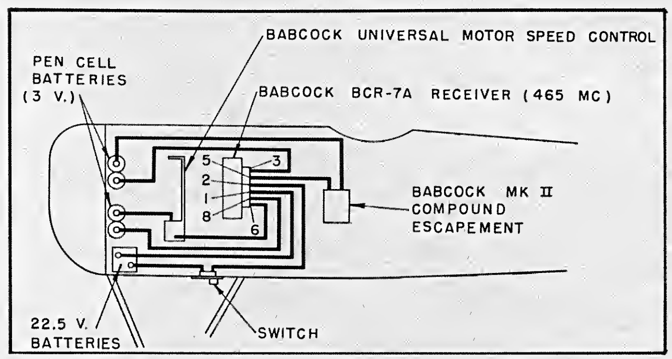
8-17 Bottom of servo board in Fig. 8-13. Wiring is cabled and anchored against handling wear and wire fatigue.



8-18 Typical schematic suggests component layout in single-channel scale Fokker D-8 by Musciano.



8-19 Schematic of single-channel rudder-plus-engine-control installation. Varies with receiver types; tubeless, relay types are simplest. Long parallel wire runs would be cabled.



8-20 Representative single-channel schematic. The receiver designated is no longer manufactured.

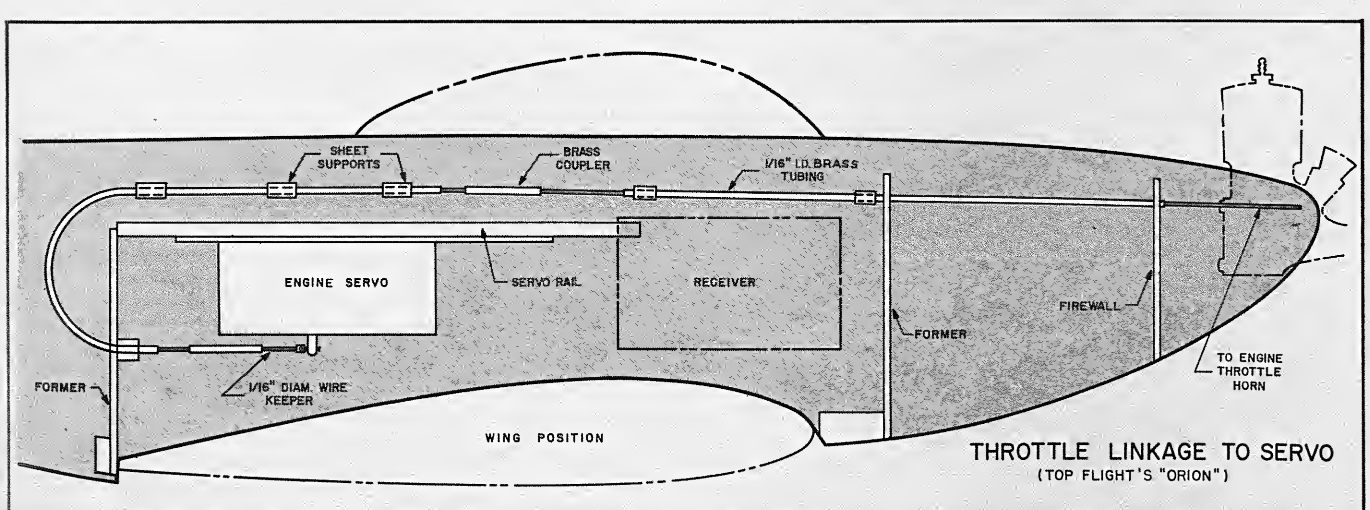
practical up to the .15 engine size. Appropriate blind nut sizes will take any required size of engine mounting bolt.

In multicontrol planes, the preference is for a separate mounting plate of Micarta or plywood (3/32″ to 3/16″ thick). The engine bolts to the plate. (See chapter 6.)

Tank installation: Any tank should be as close to the engine as practical considerations permit, because a long fuel "draw" will cause starting and running difficulties, or variations in mixture and power with the airplane's changing attitudes. The elevation of the tank is important to the type of aircraft. In a small, nonstunting plane, the fixed metal tank usually has its top level with the needle valve position, or as close to this position as possible if the nose profile does not permit. If a tank is higher than the valve, the engine tends to run rich and flood; if lower, to run lean. If a tank is very low, and/or too far away from the needle valve, the engine will tend to run lean, progressively losing power and overheating as the fuel level drops.

In the multi stunt plane, the center of either the clunk or clank tank should be slightly lower than the needle valve, almost as it would be in U-control. (See chapter 6.) Often this is not possible with an upright engine mounted high on the fuselage, in which case the tank is kept as high as the nose profile allows. When a tank is too high, the engine will tend to run rich when the plane is upright, vice versa when in inverted flight. If too low, these conditions are reversed. While the needle valve can be adjusted for any one condition, there will always be some variation in mixture between upright and inverted flight when the tank cannot be exactly located, so deviations from the correct location should be minimized.

Fig. 8-21 illustrates the nose section of an Orion.



8-21

9: TROUBLESHOOTING

MANY control failures are caused by a combination of electronic, mechanical, and human factors. Although any electronic device is vulnerable to tube, transistor, condenser or similar failure, our most frequently encountered troubles are systemwide — not merely radio, but actuators, switches, relay contacts, reed bank adjustments, batteries, switches, plugs and sockets, and things more related to maintenance and inspection.

Most failures yield to simple analysis. Common sense determines the focal point and step-by-step checking eliminates things which could have bearing on the situation. The beginner too often just "tries" things.

Aeronautical operations are, as a rule, the most critical. Range, reliability and quick response must be perfect. This discussion, therefore, is directed mainly to aircraft, although basics apply to other kinds of models in any case.

Preliminaries: The proper place for initial testing of equipment is at home. The new installation should be operated through dozens, if not hundreds, of control cycles with perfect response, before actual use. No system is reliable until it responds as required to *every* signal that is sent. It cannot be hesitant nor erratic.

With the transmitter close by, observe the manufacturer's directions. He probably has said something about retracting or removing an antenna to avoid overloading or "swamping" from an overpowering signal strength. In actual practice, such an effect should not be experienced after a distance of a few feet is placed between transmitter and receiver. Some transmitters have high and low switches to control output for such reasons.

To function properly, both transmitter and receiver must be properly tuned and have the specified voltages. Actuators and control surfaces must work freely. Wiring must be neat with good soldered joints — the bane of most beginners. These requirements easily could be expanded by many thousands of words. One simply must know how to solder, for example. The most effective thing the beginner can do is to learn in advance what he can about the particular operation, be it soldering or something else.

Power supply: The source of electrical current is the power supply, whether it be in the form of dry batteries, wet cells, nickel-cadmium batteries, or battery and power converter combinations. To generalize, all batteries must have the capacity (rated in ampere-hours or milliampere-hours) to maintain above-minimum voltages not only during a long flight or cruise, but for as many subsequent operations as might be made during the course of the day's activity.

Dry batteries: Most common is the ordinary carbon-zinc type — the familiar penlight cell is one example. Once universally used for both transmitters and receivers, dry batteries have given way to various power supplies, mostly in multi transmitters (though the dry battery is not out of the picture by any means), and to nickel-cadmium batteries for many receiver/actuator setups, particularly in multi. The carbon-zinc battery is gradually bowing out in favor of alkaline (or manganese) variations for many single-channel installations, notably where the receiver and actuator share a single voltage supply. An inadequate or defective electrical supply is an underlying source of trouble that is easily attributable to other incorrect causes.

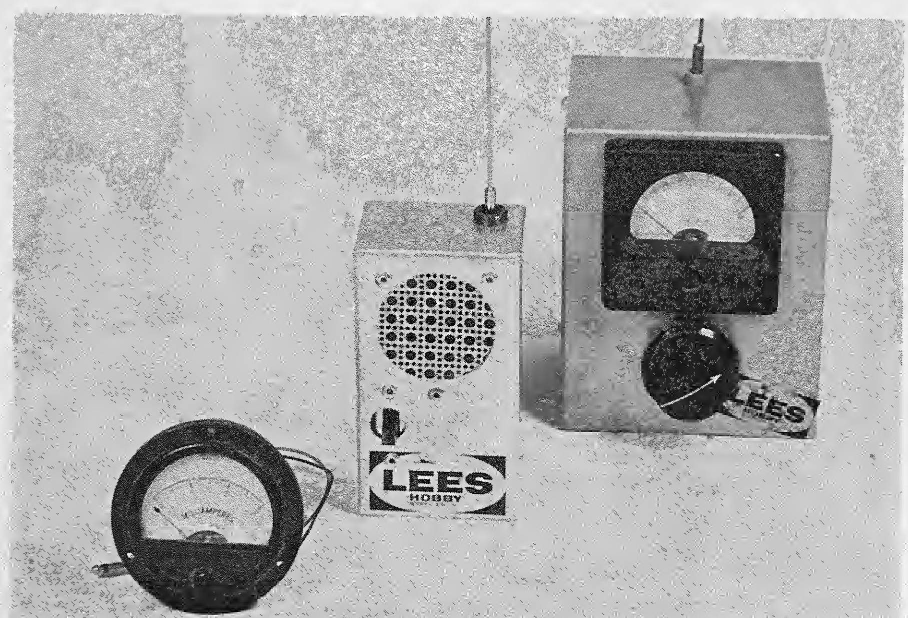
Characteristic of the dry battery is a voltage loss with each use and, with an interval of rest between operations, a restoration of voltage, but not necessarily to the original voltage. Depending on battery size, this voltage drop becomes more severe with each use, and the regained voltage becomes less. When checking dry batteries — always under load, for no-load voltages will prove deceiving — maintain the load for, say, 10 seconds. If voltage falls steadily during this interval and does not reach a point where it stabilizes above the minimum needed, the battery should be discarded.

Dry batteries are extremely susceptible to low temperatures, so if cold-weather flying is to be done, these batteries must be checked under the conditions in which they will be used. At 40 degrees or less dry batteries do not come up to their rated voltage, nor do they have their rated capacity for any length of time. This drop in voltage and capacity is more acute on really cold days.

If dropped or abused, dry batteries which consist of smaller cells connected together should not be trusted, for an open or intermittent internal circuit can be present. When wires attach with snap-on straps, these connections should be tied down by masking tape, plastic tape, or rubber bands around the wire and battery.

Manganese-alkaline cells: Similar in appearance to carbon-zinc batteries, these cells withstand higher drains and are frequently recommended, therefore, for single-channel relayless receivers where a common battery serves both receiver and actuator. They are more expensive but a virtual necessity in this case.

Although you will hear of both



Three commonly used devices, left to right: milliammeter, monitor, field-strength meter.

manganese and alkaline batteries, the correct designation is maganese-alkaline. However, either designation can be used. Mallory calls them manganese, Burgess alkaline. By either name, the composition is the same.

Wet cells: The lead-acid battery (storage battery type) sustains very high drains for long periods, but is seldom used with receivers. Since the trend to hand-held units it is seen only in larger transmitters which rest upon the ground. Service is faultless provided that the electrolyte is added according to directions and that thereafter the necessary liquid level is maintained by the addition of distilled water, and that charging rates and periods be as specified.

Nickel-cadmium batteries: These come in many sizes and shapes, button types, penlight types, etc., and are rechargeable. "Nicads"* are virtually standard in all multi aircraft, in many single-channel planes, and other situations where light weight and high capacity are required. There are two kinds of nickel-cadmiums, the sealed type (used for receivers, servos, etc., and in some transistorized transmitters) and the vented type, which has an electrolyte (for transmitters). The charging rate and charging period must be meticulously observed, especially for sealed cells. Though initial expense is high, the batteries can last several seasons.

Tuning: It is against FCC regulations to tune the oscillator section of the transmitter unless you have the required "ticket." Under Citizens-band regulations you have no such permission. A qualified person can tune the transmitter for you. (By qualified person is meant a commercial-class operator, holding a ticket for either first or second class, as issued by the Federal Communications Commission.) As the equipment comes from the manufacturer the transmitter will be operable, and in all troubleshooting it should be known to be operable before anything else is checked in the system. When you buy it, the transmitter is closely tuned to the receiver, but fine tuning of the receiver (permissible) is done by means of a ground check which places a suitable distance between the two units. However, you can tune the amplifier section, and/or antenna tuning, of the transmitter. This requires the use of a field-strength meter at least. A monitor (used on the field to audibly insure that the transmitter is keying properly, to detect interference, etc.) is of some help when tuning. It enables one to hear the various tones and transmitted signals.

Most common mistake made in tuning the transmitter is to peak out the oscillator. By tuning for absolute maximum output from this stage, the transmitter can go out of oscillation at some critical moment. It will be noted, usually, that as the oscillator is peaked, the field-strength indicator needle will follow, but when over-peaked the indicator will fall abruptly toward zero as transmitter oscillation ceases. If the tuning device is turned in the opposite direction after oscillation is restored, the indicator reading will fall off slowly. It can be said only as a generality that the tuning should be positioned just short of the peak reading. Some transmitters demand a good understanding of such things because what appears to be suitable tuning can adversely affect percentage of modulation and other factors.

Amplifier and antenna tuning are touched up after the oscillator stage has been tuned. Very often this is all that is necessary to restore familiar signal strength, without touching the oscillator. Assuming suitable voltage, it is advisable to check amplifier tuning (and antenna tuning, if any) before touching something else.

Voltage drop is a common cause of transmitter failure. If unexplained difficulties arise with a tube transmitter, have the tubes checked. Marginal and erratic performance which will be blamed on many other things quite frequently is due to a doubtful transmitter tube. Loose antennas, or loose connections to antennas — notably when antennas insert through the top of a hand-held unit — are common failure points. Fatigued wires with dry-battery transmitters require frequent inspection. Dirt and oil film (and specks of solder) in lever switches are elusive troublemakers.

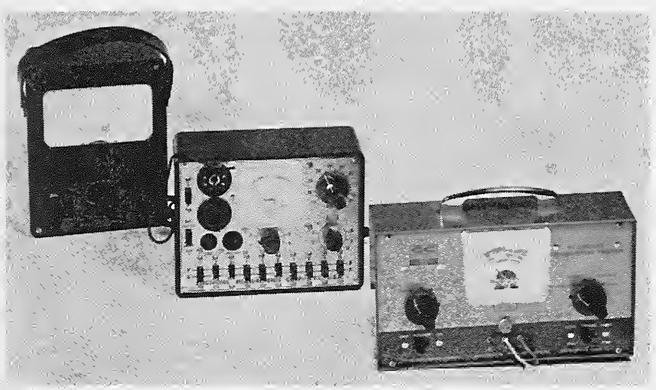
Incidentally, protracted playing around with transmitter tuning is not good for the equipment, because in certain conditions high drains are experienced. Improper but usable tuning may run down batteries quickly. Crystals and tubes sometimes can be overheated.

Receiver tuning: To tune the receiver it usually is necessary to adjust only one control — the RF tuning slug. If the particular installation calls for the use of a meter, the best tuning corresponds to the highest meter reading. Sometimes earphones are used, as specified, to tune for maximum-strength clear tone. However, many single-channel receivers are tuned by reading for maximum voltage at the escapement. Once tuned, the receiver should not require more than a short ground check for a considerable period of time.

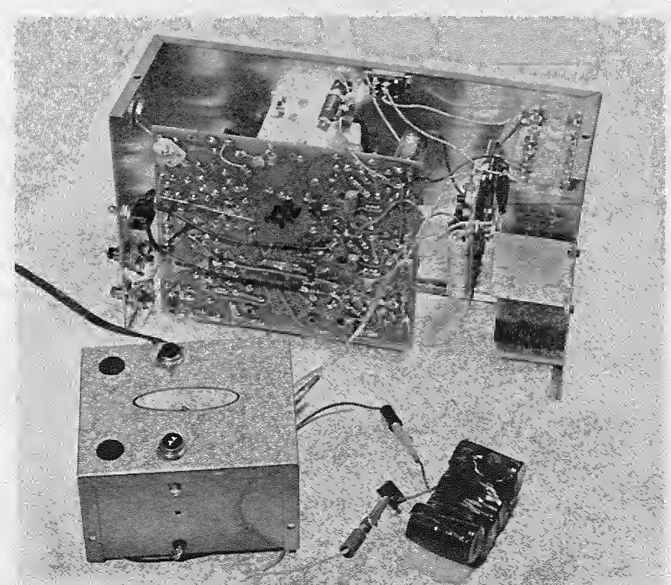
When is it considered tuned?

It will be noted that when the receiver and transmitter are near each other, receiver tuning is broad; that is, the tuning slug can be turned consid-

*"Nicads" is popular terminology for nickel-cadmium batteries, but the word Nicad is a trademark used by Gould-National.

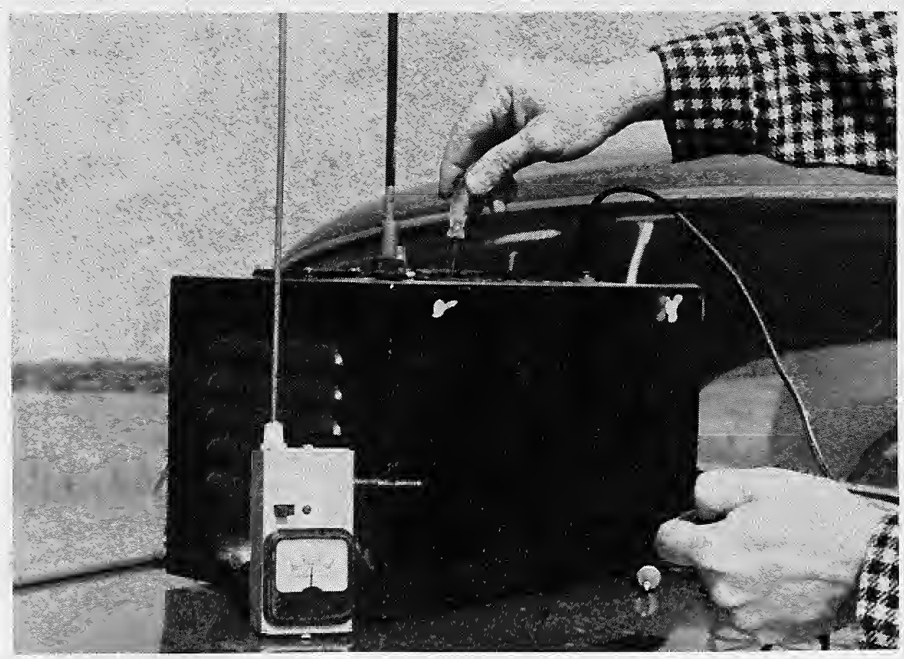


Left to right: multimeter, tube checker, and transistor checker. Multimeters are practically a must; the others are "luxuries."



Right: With rechargeable batteries, a charger is important. Some manufacturers design chargers for their own radio equipment. This Dee Bee charger simultaneously charges batteries in transmitter and receiver-servos (foreground) at proper rates.

erably to either side without losing the signal. However, as distance is increased between the two, the amount that the slug can be turned without loss of signal becomes less and less until, at extreme range, it cannot be turned at all. It should be possible to operate any equipment at a 600-foot minimum distance on the ground. This varies with transmitter output and receiver sensitivity, and a ground check distance of more than 1000-1500 feet is nothing for some equipment. For practical purposes, ground checks usually are made with antenna collapsed to reduce the distance required for testing. For example, a multi transmitter which will operate simultaneous controls cleanly at a distance of 150 to 200 feet with antenna collapsed is deemed to have sufficient air range for all normal operations.



Field-strength meter, foreground, indicates relative strength of carrier wave. Only a properly licensed operator may tune the oscillator section of a transmitter.

Escapement systems: With relayless receivers, troubleshooting escapements often requires a checkout of the entire system. We must know that low voltage, faulty receiver tuning, etc., are not at fault before making hasty adjustments to the actuator.

An escapement is similar to a relay in that it has a spring-loaded armature and a wire-wound coil which is energized (like a magnet) by a flow of current. The twisted rubber only supplies the "muscle" to turn the escapement shaft, moving the control surface, when the device is triggered by the signal which closes its circuit at the receiver. The energized coil pulls in the armature against the coil end. However, the armature will not pull in until the magnetic force is large enough to overcome the opposite pull of the return spring. When the signal is discontinued, the coil is deenergized and the spring pulls the armature back to its neutral control position — if the tension of the spring is sufficient. From these simple facts we can deduce many causes of common failures and correct them.

Failures fall into three categories: (1) failure to pull in, (2) failure to drop out when signal is relaxed, and (3) skips with (a) motor running or (b) with motor not running.

Does not pull in: Usual cause is insufficient voltage. Less frequently, but commonly enough, mechanical loads are too high because of linkage binds, excessively heavy and/or overwound rubber, or too high a spring tension setting. If the system works easily mechanically, and voltage is adequate, spring tension can be lowered slightly (if necessary) by bending the tab on the frame to which the spring attaches; but there must always be sufficient spring tension remaining to make the escapement return to neutral with no signal on fully wound rubber. (With a relayless receiver, if the receiver idling current remains high enough with no signal, the escapement cannot drop out [especially with low spring tension]; with a relay, if the relay is improperly adjusted or has damaged contacts and does not drop out, then also the escapement cannot drop out.)

Low voltage: With signal on (relay is closed if there is one), read the voltage at the escapement — never at the batteries nor at any point before the receiver. Consult, if necessary, the data sheet for both receiver and escapement to see what normal voltages are specified — be familiar with these figures. When the rubber is fully wound, a certain voltage will be required to pull in the escapement — for example, 2, 2¼, 2½ volts. Anything less, therefore, will not operate the device (unless spring tension is deliberately lowered). Dry batteries require frequent checking because with continuous operation voltage falls off (escapement drain is far more than receiver drain) and can fall beneath the minimum required. For true reliability, this voltage should read (under load) above the minimum needed. (Fig. 9-1.)

If no voltage is evident at the escapement, first check at the batteries; then, if necessary, at key points in the system, such as after a switch or jack to make sure these items function, or that there is not an open wire or circuit. An ohmmeter is helpful for checking continuity (current off). If voltage is present but too low at the escapement, and also low at the batteries, new batteries are required. There may be a slight voltage drop between the batteries and the escapement due to wire resistance or receiver components — notably in the case of relayless receivers having a single voltage source. A modest drop of two or three tenths of a volt may be normal, but a severe drop is due either to poor receiver tuning, low transmitter output, or possibly a component failure — provided batteries are okay.

Low voltage with relayless receiver: Very few of these single-channel 3-volt receivers can be operated reliably on standard penlight batteries (two 1½-volt batteries in series). Most manufacturers say flatly not to use dry cells for such receivers, because of the high electrical load of actuator and receiver combined. They recommend alkaline or nickel-cadmium cells. However, an alkaline battery (it is a dry battery) will show voltage drop with use, though life is superior. With dry batteries, the relayless-receiver on-signal current presented at the escapement may be, for example, 2.8 volts, and with subsequent voltage drop does not leave an exciting margin of safety about the pull-in current of some escapements. However, should the spring tension have been increased to assist the escapement to drop out, the pull-in margin can be small if not nonexistent.

With nickel-cadmium batteries, the usual choice is between two in series for a total of 2.4 volts, or three for 3.6 volts. The lower figure requires that escapement pull-in voltage be in the neighborhood of 2 volts maximum. The higher voltage insures pull-in, even if spring tension must be raised for reliable dropout. However, some receivers will not oscillate at this higher voltage and others may be

damaged; maximum receiver current (for a 3-volt receiver) is generally about 3.4 volts. The capacity of appropriate Nicads is a minimum of 225 milliampere-hours (450-500 mah. recommended if weight can be carried).

What happens to the aircraft with these particular malfunctions? If the escapement will not pull in, the model is out of control and can fly away — usually blamed upon interference or the radio. If the escapement cannot drop out, the plane will spiral into the ground after rudder is applied, because control cannot be neutralized. We can consider two additional conditions. As distance is put between receiver and transmitter, the current rise in the receiver on-signal is less until, at the out-of-range point (hence importance of good tuning), it will not rise high enough to operate the escapement (or a relay). With intermittent control at a critical distance, control is erratic; also, when signal is held on, the escapement (or relay) will sometimes release of its own accord. Such conditions as a high temperature — well above 90 degrees (which can be much hotter inside the plane) — can contribute to the escapement's not dropping out.

Frequently, there is a slight "leakage" of voltage through a transistor, and this additional voltage (in relayless types) can reach — due to high temperature and voltage — the actuation point of the escapement. This is one reason the practice of using low spring tension with an escapement (such as ½-volt pull-in) is most dangerous. Moreover, low spring tension of a relay or escapement makes those units most susceptible to engine vibration (giving unwanted controls or even skipping of the unit).

The conclusion is that, with transistorized relayless operation in single-channel, the escapement must be carefully adjusted — if it does not work properly when you buy it.

Residual magnetism: Regardless of type of receiver, but occurring more often with voltages higher than those recommended for the escapement, some actuators may exhibit a residual magnetism which continues to hold in the armature after the signal is cut off. The cure is to place a piece of Mylar or cellulose tape over the end of the coil, so that the armature cannot touch the core when pulled in.

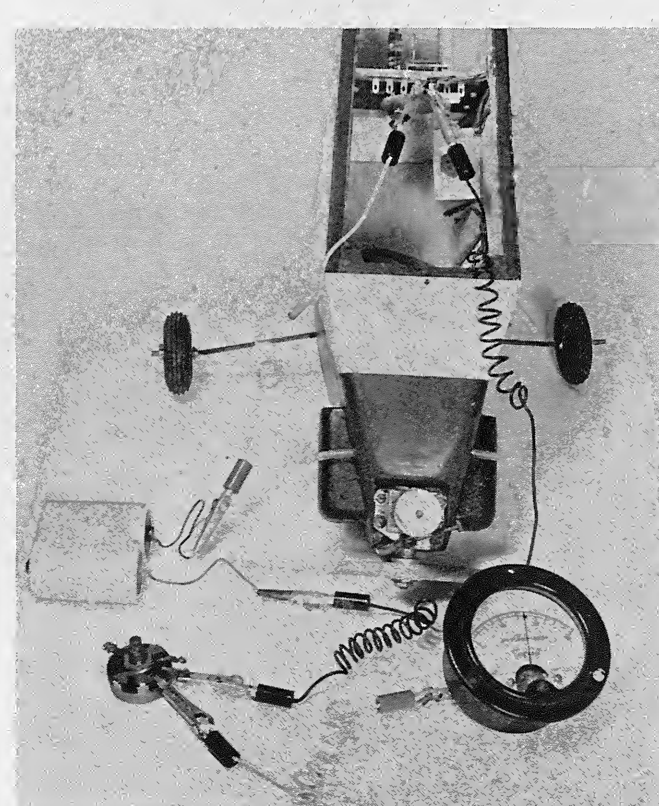
Escapement with relay receiver: Since the relay is a switching device, and actuator current does not flow through the receiver circuitry but only through the relay when the live contacts are closed, higher voltages, limited only by the escapement itself, can be used without damage to the receiver. Some escapements will take 4½ volts, which allows a rather high spring tension setting, making operation less marginal.

For example, some modelers use 4½ volts with a Vari-Comp escapement. This voltage allows raising spring tension even to a point where the device would not pull in on 3 volts. The increased tension insures dropout even with heavy rubber and many rubber turns. Such adjustments are more common on ¼" black rubber.

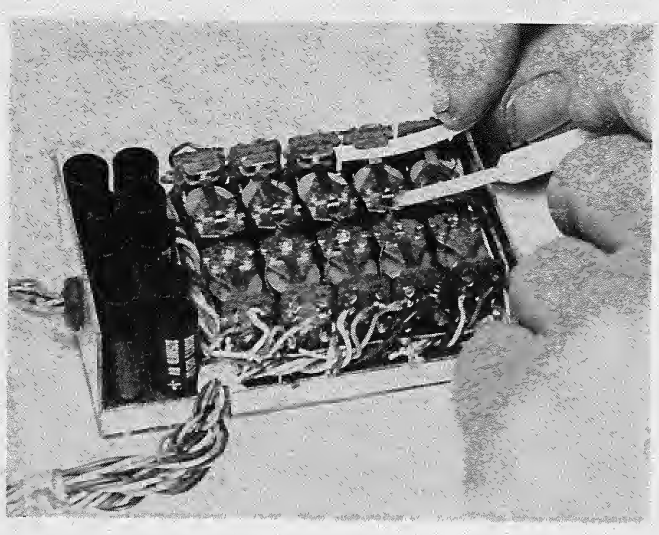
With the single-channel relay receiver, separate actuator batteries can be used — always superior when weight can be carried. For 4½ volts, three 1½-volt cells, any type, will work — though standard penlight cells are relatively inferior, especially since current drain rises when voltage is increased while resistance (ohms) remains the same. Alkaline cells are not essential, but are recommended; and three nickel-cadmiums at 3.6 volts with 450-500-mah. capacity are ideal.

Procedure for escapement spring adjustment: It is necessary to know precisely at what voltage the unit pulls in and drops out when you adjust an escapement. One system is to insert an appropriate pot or rheostat in series with a lead to the escapement, adjusting this control to vary voltage up and down to see just where pull-in and dropout occur—with rubber fully wound. The voltage is read by meter. The test control should be used with independent batteries and with the receiver unplugged; use alligator clips to attach the test equip-

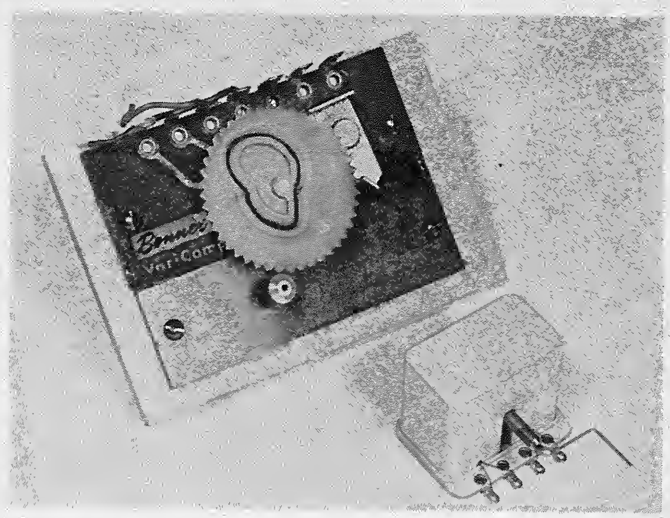
9-1 Voltmeter (a necessity) is being used to check actuator batteries at the escapement. Instrument shown is an inexpensive multimeter useful for reading resistances as well.



9-2 How to check escapement spring tension: potentiometer and meter in series in one escapement lead, using an outside battery. With rubber wound, pot is turned to vary current.



9-3 Cleaning relay contact: Press armature down to squeeze thin paper against the contact; then pull paper through.



9-4 Basic single-channel actuators: top, compound escapement; below, magnetic proportional actuator for pulse systems.

ment leads to the escapement. (See Fig. 9-2.)

Another method, with receiver and transmitter on, is to collapse the transmitter antenna to lower the signal strength. If the distance between receiver and transmitter now is increased, or if the transmitter position is altered by pointing the antenna away from the airplane, it will be noted that the reading of the meter will vary. By suitably making these transmitter movements, the current at the escapement (and on the meter) can be made to rise or fall, thus checking the points where pull-in and dropout occur. Increasing spring tension raises both points, and vice versa.

Low voltage with relay receiver: If voltage is present at the escapement, a low reading (signal on, relay closed) is due to poor actuator batteries. If there is no voltage at the escapement and all batteries are okay, the trouble probably is at the relay. If the receiver is working, the relay armature will pull in with signal, even if the escapement does not operate. Either the relay contacts are dirty or they are not closing firmly. First clean the relay contacts by holding a scrap of typewriter yellow sheet or Mimeo paper between armature and contact while the paper is pulled through. Repeat until clean. Relay contact burnishing tools should be used sparingly because the abrading action can roughen the contact so that pitting and sticking occur.

If the escapement still does not work — if no voltage is present — contact pressure is insufficient to close the circuit. Press the relay armature lightly against the contact. If the escapement works now, the relay contact either is still dirty or requires adjustment — that is, an almost imperceptible bending of the contact arm toward the armature (or turning any adjustment screw). Sometimes the armature (if it is thin and flexible) requires a slight bending toward the contact, so that it meets the contact firmly when actuated.

Relay adjustment is very difficult for the beginner. Increasing spring tension raises both pull-in and dropout of the relay only. The armature should never touch the pole piece of the coil — a barest sliver of light should show through this gap when the armature is pulled in. Moving the normally closed (idle condition) contact out increases relay current required to pull in.

Naturally, there are many such combinations, depending on which receiver you own. Too-close an adjustment between pull-in and dropout makes the relay susceptible to vibration, as will an excessively low spring tension. But there must be a considerable range of current variations both above and below the normal relay operating range, for, like the escapement, the relay may not pull in nor drop out if spring tension adjustment is bad. Such adjustments can be done only with an understanding of the particular receiver and relay operating characteristics and the use of some means of varying current to the relay while testing. An appropriate milliammeter is essential.

Probably the best advice is never to tamper with the relay, and merely to keep the contacts clean, as long as it functions. (See Fig. 9-3.)

The current (flowing through the relay coil) which operates the relay varies greatly with voltage and circuitry. In a tube and relay receiver the current must be relatively low, such as 5 mils signal on. With a low-drain transistor receiver, the current through the relay can be, say, 40 mils — or much higher — without killing batteries. Manganese-alkaline or nickel-cadmium batteries can stand drains up to 50-60 mils with roughly the same life characteristics as a 22½-volt B battery at 5 mils.

An example of relay setting for 5 mils would be pull-in of 3 mils and dropout of 2 mils.

In many cases, the relay receiver has a B battery (tube-type receivers). This B voltage flows through the relay coil and is the voltage that is varied, signal on and off, to energize the coil sufficiently to operate the relay armature. If the B battery is weak, the current rise is less, and eventually — even if the radio still works — will not be enough to operate the relay. (This usually happens first when the craft is at a distance from the transmitter: with very high relay spring tension, range is reduced for the same reason.)

Pulse actuators: From .049 engine size up, most of these actuators use a Mighty Midget motor which eventually suffers brush wear. Precautions should be taken that new brushes are inserted exactly as prescribed by directions. Fliers having the most success with this actuator always anchor the brushes in the Mighty Midget, nylon wrappings around the brushes and the motor itself being the preferred method. The brushes generally are tied by wrapping fine nylon cord around them to prevent their coming out due to engine vibration.

Basically, pulse systems (single-channel) are similar to escapement systems. The difference is that instead of the operator keying a signal, a pulser unit, at the transmitter, makes and breaks the circuit rapidly to vary the pulse lengths. So the underlying requirements of tuning, checking voltages, making ground checks, all are common to both systems. The pulse fan often does work with more electronic gadgetry, such

as pulse omission detectors with the receiver to actuate a motor control.

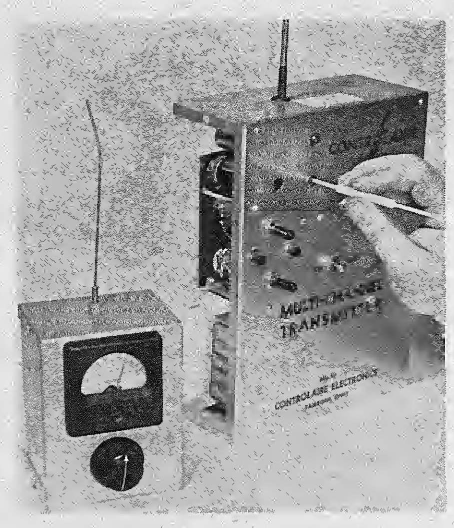
For small craft with .049 or less power, practical magnetic-type actuators exist. These, when used with commercial electronic pulsers, involve few if any troubles that are not found in any single-channel arrangement — where the actuator is concerned, less. Above this size, the pulse field has many practiced devotees capable of putting a finger on any electronic malfunction. To minimize troubles, therefore, we suggest that, if you do wish to use pulse from the beginning, you start with the magnetic actuator in a small craft. (Fig. 9-4.)

General single-channel: Troubleshooting is simplified if it is remembered that the receiver is only a remote-control switching device which closes and opens a separate actuator circuit. The receiver is switched on and off, as far as the actuator is concerned, by the transmitter. This gives three distinct areas to investigate when the actuator does not function: (1) actuator and its batteries and circuitry; (2) receiver, its batteries and hookup circuitry and associated components such as switches, jacks, plugs and sockets; (3) transmitter and its power supply. Troubleshooting is not effective unless it is known that transmitter and receiver are properly tuned and have adequate working voltages.

Accessories — single and multi: A tremendous amount of trouble is caused by switches (intermittent with vibration), jacks, plugs and sockets. To eliminate these vague causes of failure it is recommended that:

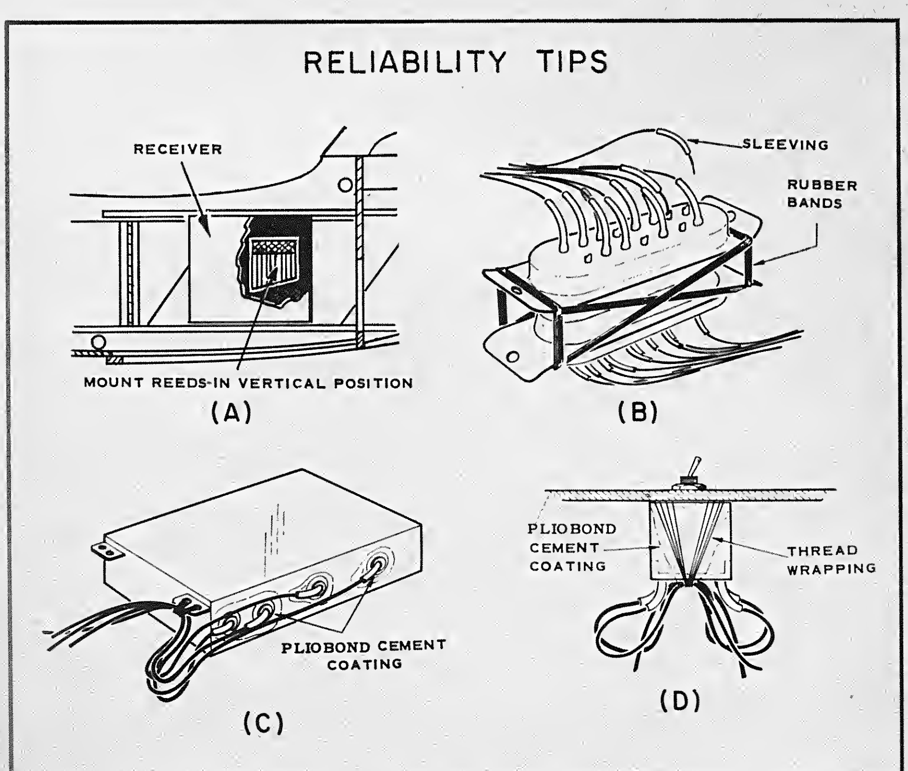
1. Switches: Either high-grade toggle or knife-action slide switches should be used. For a toggle switch, one can never spend too much money. Never use a pressure-type slide switch. Select double-pole switches (they have two circuits) and use both sides (even for one lead) so failure of one side will not break the circuit.
2. Plugs and sockets must always be tight fitting. Avoid a heavy plug in a fixed socket, because vibration and shock will tend to detach the plug. If possible, use high-grade miniature plugs and sockets (such as Winchester), or connectors (such as Orbit). Connectors are almost standard in multi.
3. Always insert a shorting plug in a closed-circuit jack, which insures a reliable circuit even when the contact pressure of the jack is weakened from much use.

General multi: Multi divides into two popular categories: the reed systems and the proportional systems. The reed systems, being rather standardized, make it relatively easy to localize common failures, but proportional, having several radically different basic approaches and a generally more exotic circuitry, is not generally conducive to described procedures, except for the usual admonishments to observe power supply requirements and tuning procedures described by particular manufacturers. Proportional equipment is sold as a systems package, including correct batteries and usually the manufacturer's own charger. Severe troubles will require the manufacturer's attention. What follows is keyed to reed systems, but has occasional application to proportional as well.



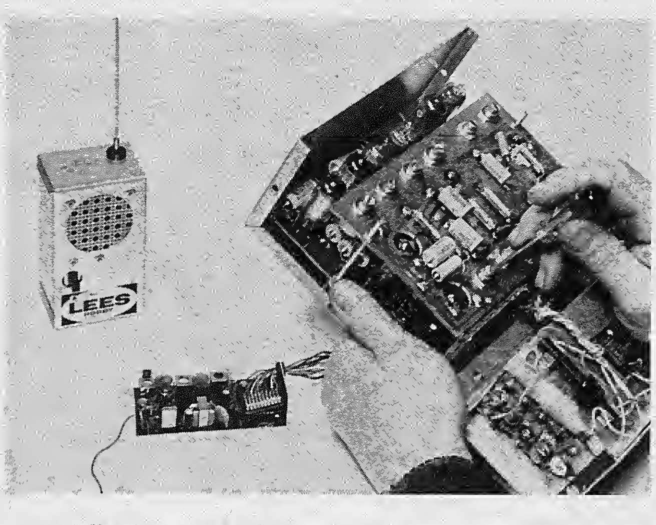
Tuning the amplifier stage of a multi transmitter. Note indication on dial of field-strength meter. Tuning should be done with full-length antenna.

Multi transmitter tuning: A common cause of lost or fuzzy individual

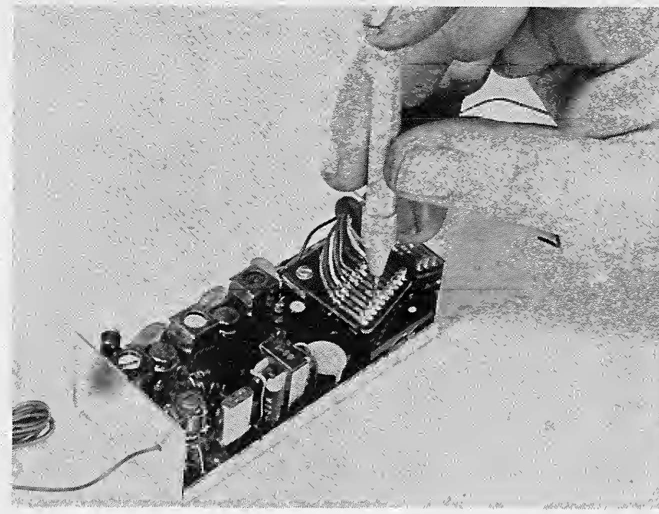


(A) With upright engines, this position of reeds minimizes vibration effects. (B) Sleeving prevents soldered wires from breaking off, while rubber-band wrapping maintains tight connnector. (C) Battery box and battery pack wires must always be anchored to prevent certain breakage. (D) At switches, etc., wires should have sleeves and be anchored.

Ground checks can be performed with a helper at transmitter. Upheld hand means hold-on signal.



9-5 Adjusting a control pot for one channel. Changes in tone are heard over monitor. Reeds can be observed directly if necessary. Left hand is holding a lever switch.



9-6 Adjusting a reed bank screw for improved contact with agitated reed.

controls is improper tuning of the potentiometer which adjusts that particular tone in the transmitter. A 12-channel transmitter will have 12 such "pots," and so on. If the pot is too far out of adjustment it may pick up the wrong control. At a distance you then sometimes get, sometimes lose, the control in question.

Manufacturer's directions describe this tuning. In the reed system, the audible pitch of the vibrating reed will reach maximum agitation at some point as the pot is slowly turned, first toward one side, then the other. (Fig. 9-5.) Normally, the proper adjustment is just slightly below maximum agitation, though directions often specify maximum. If reed agitation is too weak, the circuit to the actuator may not be closed or will be intermittent, making the control surface seem to chatter. If the pot is too peaked out, the reed involved may not start to vibrate with every signal.

Not only must each reed vibrate suitably when keyed by its transmitter control, but it must be able to do so when another simultaneous control is held on. This adjustment is made by holding on one control while the pot for the simultaneous control to be tried on and off, is adjusted. Fine tuning is performed by backing off, say, 10 feet. This is not easy for the beginner. If reeds are poorly adjusted, additional channels can be spuriously driven, perhaps momentarily, because one reed will cause a sympathetic vibration of an adjoining reed if their cycles per second are too close. Know which pot controls which reed, marking adjacent to each pot the initial of its control.

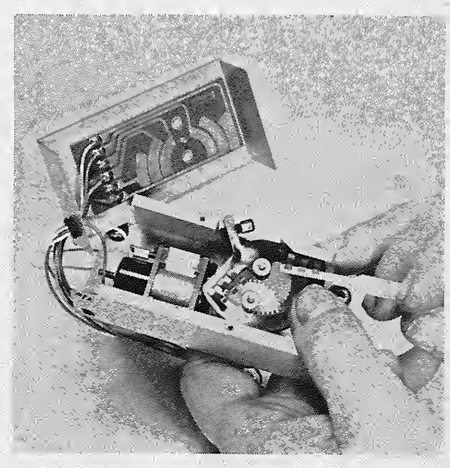
No control: By this is meant that no servo will operate — the radio is dead. First step is to ascertain whether the trouble lies in the receiver or the transmitter. If you fly multi, it must be assumed you have a monitor. When no signal is sent — transmitter is turned off — you will hear a rushing noise in the monitor (those including a super-regen receiver). When the transmitter is turned on (but no signal is sent) the carrier of the transmitter should quiet this rushing noise. (Be sure monitor is tuned to transmitter.) Similarly, a field-strength meter will indicate reception of the carrier. If neither of these conditions occurs, the transmitter is inoperative, and the usual checks are required, beginning with voltage. Sometimes it will operate with antenna partly telescoped, but not with antenna at full length — an indication of tuning trouble.

If the transmitter has six or less channels and no simultaneous control feature, it is possible that the oscillator stage is out because of a bad tube, tuning, etc.; but in simultaneous transmitters which have two oscillators, failure of one oscillator means that all controls on that side of the unit will be inoperative but those on the opposite side will function.

Most transmitters have a tuning bulb which glows when there is transmission, and the intensity of the light varies with keyed signals. If the transmitter is operative and keyed signals can be heard on the monitor and the system remains dead, the receiver should be checked for battery voltage, tuning, then bad switch, broken wires, loose plugs, etc. A common cause of detuning is a loose-fitting tuning core in the tank coil which moves with vibration; a thin coating of wax on the threads will make a tighter fit.

Individual control failure: Since other controls function, the transmitter and receiver are not inoperative. Before removing a servo from the vehicle, ascertain if the signal-on tone for the defective control is audible on the monitor. If it is not, check the appropriate lever switch contacts; contacts may be dirty (as happens) or may not make with sufficient pressure. If a tone is heard, but sounds weak or raspy, adjust the appropriate transmitter control pot to strengthen and sharpen the tone and increase agitation of the reed in the receiver. If the reed appears and sounds sufficiently active, check that it is making good contact. Sometimes the reed adjustment screw requires very slight tightening — usually not more than a quarter turn — to improve this contact. (Fig. 9-6.) If yours is a relay receiver and these things have been done, check for dirty relay contacts, then relay contact pressure (as previously described). If the trouble is not now corrected, the servo will have to be removed for examination.

Servo failures: Most common causes are weakened or broken wires and poor finger contact pressure. For example, on the Bonner servo, the contact fingers should be barely visible when the eye sights across the top

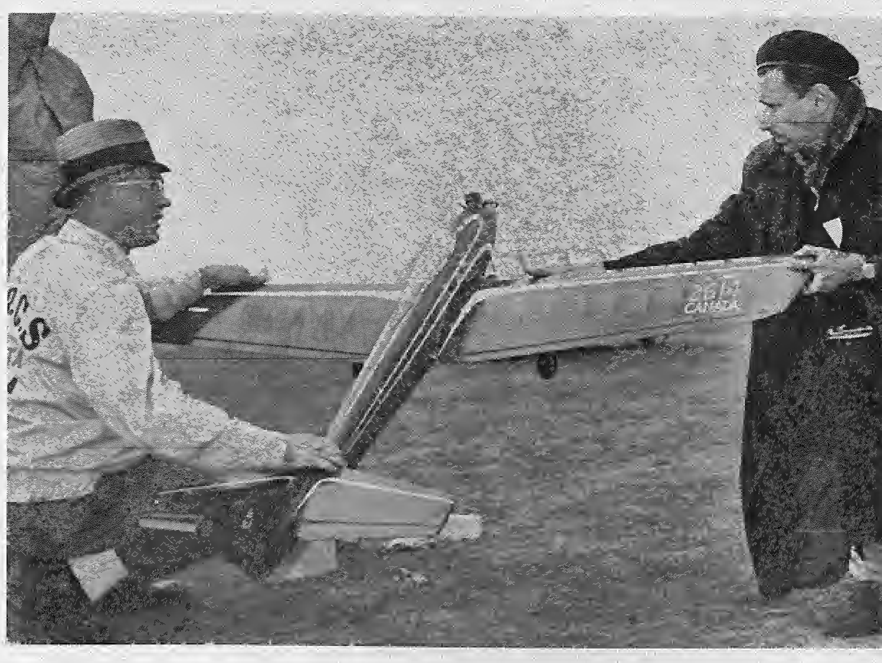


9-7 Adjusting servo contact finger for increased pressure on printed-circuit board (visible in lid).

of the open servo (lid off) from one side of the case to the other. If they are not, the arms should be bent up slightly until the ends are visible. (Fig. 9-7.) Broken wires can be check by reading for voltage at each soldered joint at the servo — signal on when necessary; or a continuity check can be made of individual wires.

Inspect for cracked or broken sector gears, etc. A tiny piece of solder can short out printed circuitry in the servo. If a careful check isolates no causes, it is possible that a transistor is burned out — which requires that the beginner obtain help or service.

Wire failures usually occur where they attach to the servo — frequently one of the power leads to the servo motor — or at the soldered joint in the multipin connector, sometimes at a reed-bank or relay terminal. Tight wires (without slack) and rough handling (pulling on harness), plus vibration, result in wire fatigue failures. Solder should not be permitted to run up inside the wire — breakage is inevitable at the end of the solder.



9-8 **New multi models should be checked against vibration by holding off ground by wing tips, engine at full throttle. In this picture the check is halted while engine throttle adjustment is observed in nose-high attitude. (Aeromodeller pic.)**

Good ground range, no air control: Assuming a good ground check, a fairly common, exceedingly difficult problem to troubleshoot with all systems is engine vibration, one factor which exists in flight and not on the ground. However, the effects of vibration are not always obvious. For example, electronic "noise" will be created by rattling metal linkages; switch contacts may go intermittent; battery box contacts may permit battery movement, changing voltages and creating more noise from rubbing contacts on metal. Did you try the radio with engines running, before flying, if possible with the craft loosely held by the wing tips? (Fig. 9-8.)

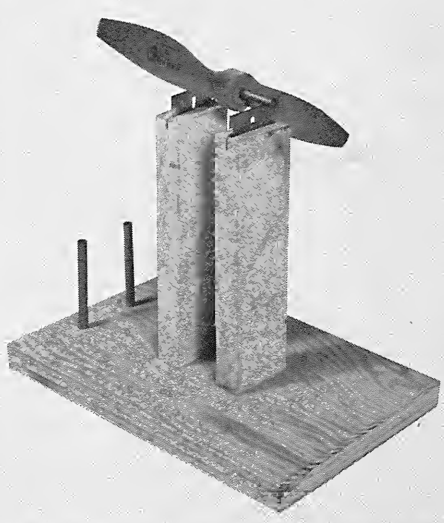
The perfect installation, which we seldom see, would have no metal-to-metal installations, nonmetallic pushrods, completely grounded equipment including the engine, and the minimum of plugs and sockets — better, none at all. Until such desperate measures are taken, one can never be sure about mysterious aerial failures commonly attributed to interference, or "that manufacturer's transmitter," etc.

Changes of position of the transmitter, if there is a bad battery connection or cold-soldered or "resin" joint, may show no air control, whereas when held at some convenient position for ground check, it may seem to operate perfectly. A transmitter antenna or internal connection to antenna may be loose. (Screw on tight.) If the trouble cannot be found, install a new or different type of switch.

If you live in a well-populated area and use super-regen equipment, interference may be at fault, but, if so, results should be variable, not always failure.

Vibration: In addition to the effects of electrical "noise" caused by rattling metal-to-metal parts, vibration can directly influence control actions. By causing reeds to vibrate spuriously, or relay armatures to open and close intermittently or to refuse to hold in, actuator circuits are closed and controls applied. Escapements sometimes cycle through, or are unable to hold on. One important test is to have the new airplane held loosely by both wing tips, engine running, and to try all controls to detect unwanted control movements without transmission.

The following practices will prove of interest: In the escapement airplane it is advisable to avoid bigger power plants than kit or plan directions specify. All receivers should be soft-mounted, particularly those having relays and reed banks. Quite frequently, when the receiver mounting is softened (on or wrapped in foam rubber), vibration symptoms vanish. Receivers should never touch a rigid part of the structure. If vibration is known to be a trouble factor, the receiver should be positioned relative to the direction of the piston stroke, so that reeds point in the direction of piston travel (usually vertically), and relays so that the armatures do not move in the same direction as the piston. In escapement systems, extra-long wire arms should be avoided.



9-9 **Propeller balance should always be checked on a mandrel. Metal rod rolls on razor blades. Bars of other diameters stand in platform holes at left.**

Engine and propeller balancing are important. Some engines run more smoothly than others. A distinction should be made between rough running, which shakes things, and very high-speed running, which causes a resonant vibration between engine and, say, a reed. The greatest single cause of vibration is propeller imbalance. All props should be carefully balanced by inserting a piece of metal tubing through the shaft hole, then resting the tubing upon two parallel knife edges (razor blades). (See Fig. 9-9.) The heavy prop blade should be lightened by careful scraping of the surface with a sharp edge. Never combat vibration by changing needle valve adjustments, because at some flight speed vibration symptoms can reappear. If vibration takes place only at peak r.p.m.'s, an increase to the next size prop diameter or pitch may eliminate it.

10: MISCELLANEOUS TYPES

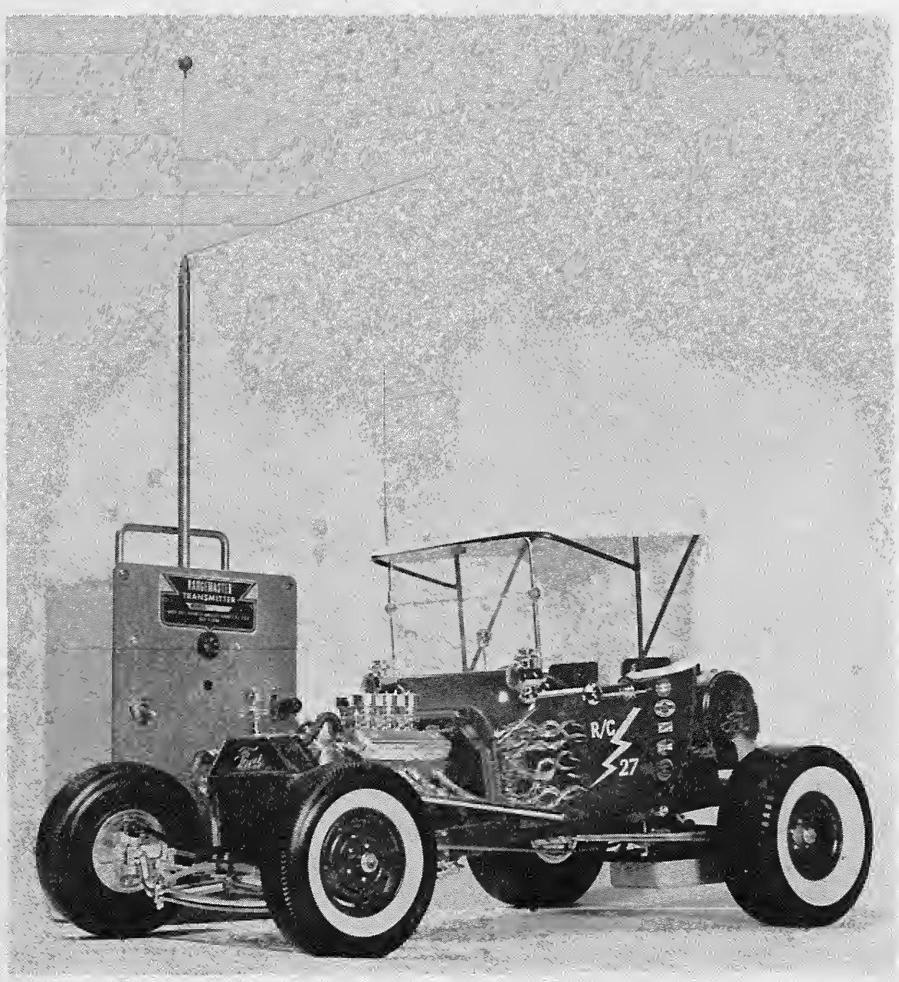
WHILE most radio-control enthusiasts admire the so-called "exotic" projects — roughly described as anything that is not an airplane or a boat — relatively few seem to have the courage to tackle the unusual model. There is an implication that the hobbyist must be a mechanical and/or electronic genius. The truth is that few such models are more complicated or more time-consuming to build than a multichannel aircraft or racing hydro.

Some projects, including aircraft, can be very complex indeed — if the builder wishes it that way — so we should be prepared to distinguish between the elaborate and the simple ways of doing things and not always assume that the "strange" model must necessarily be highly involved. In planes we have both extremes: both single-channel with rudder-only control, and multi proportional control with steerable nose wheels and wheel brakes. In boats there is the simple electric-motored craft which can be steered about at modest speeds and, let's say, the high-speed PT with expensive custombuilt four-cycle, four-cylinder engine and remote-control flag raising; and even boats with both internal combustion and electric drive so that if the former stops, the latter can be switched on to bring the craft to shore.

Once we perceive this range of choice between the fundamental and the ultimate, we realize that no type of vehicle is beyond the talents of the R/C fan if he matches his approach to his means. Most projects — hereafter we use the word project to refer to things other than planes or boats — are more or less scratchbuilt. This, perhaps, is the principal deterrent to popular acceptance of such projects. Kits are seldom available. Rather than go through the long process of obtaining scale drawings of a car, bus, or other vehicle, the builder with a yen for something different, which he can operate in the house — or anywhere — often turns to toy items which catch the eye. This is why army tanks and other track vehicles are seen so often with radio added. Surprisingly, perhaps, there are relatively few cars or trucks because, outside of the hobby shop variety of plastic builtup car kits (whose usefulness often goes unrecognized) there are relatively few manufactured cars deemed attractive enough to adapt to radio.

A seeming contradiction is the submarine, which is frequently modeled. Its novelty and its mode of operation are so engrossing and challenging that quite a few people have braved what are assumed to be formidable obstacles. And yet, even the sub is not the supreme challenge it is rumored to be — as we shall see.

In this roundup of projects we shall touch upon both the simple and the complex, always with emphasis on the underlying systems. While it is not possible to completely detail these interesting vehicles, we can convey the general idea of how they operate. With an understanding of the basic system suitable to each type of vehicle, the enterprising hobbyist should have less trouble in the future adapting these ideas to his own use for either a simple or an elaborate rendition depend-



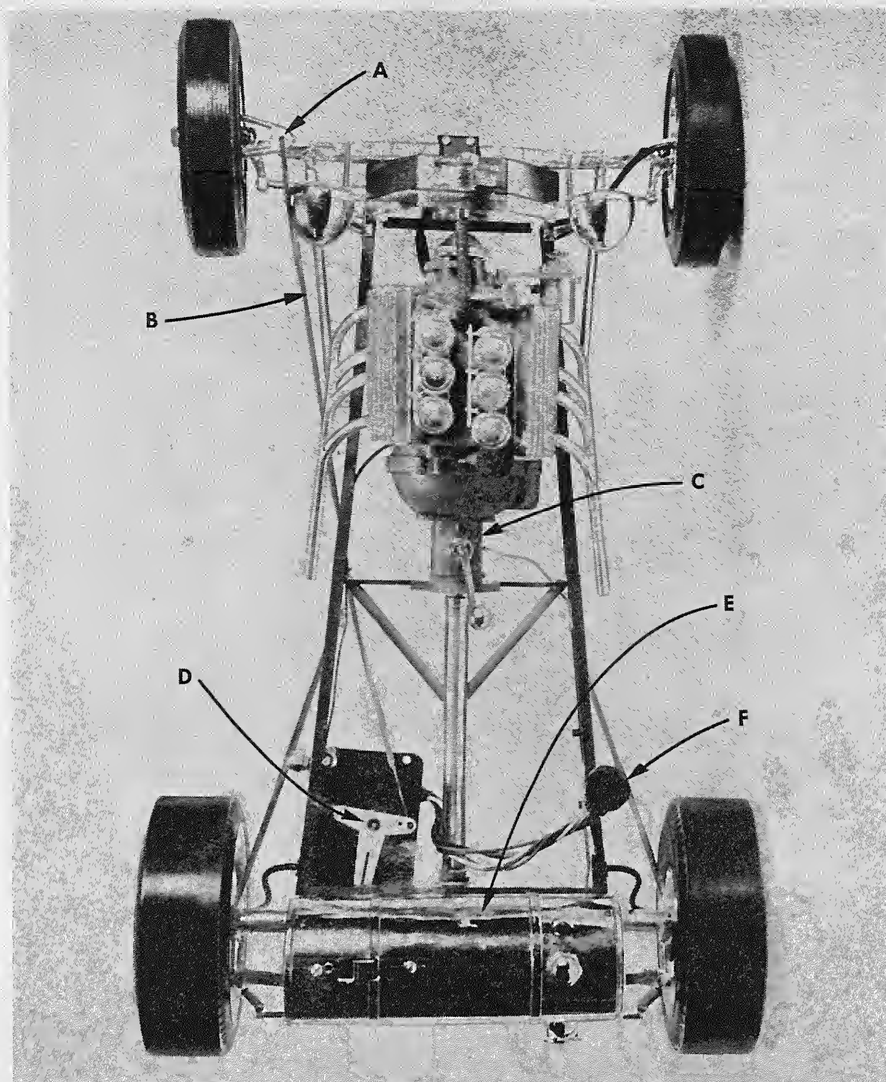
10-1 **This Lindberg motorized Bobtail T (by Aubrey Kochman) is typical of large plastic model cars adaptable to radio control. Unimatic steering machine (added) can be seen between the rear wheels. (By courtesy of American Modeler.)**

ing upon his mechanical experience and the availability of radio-system items.

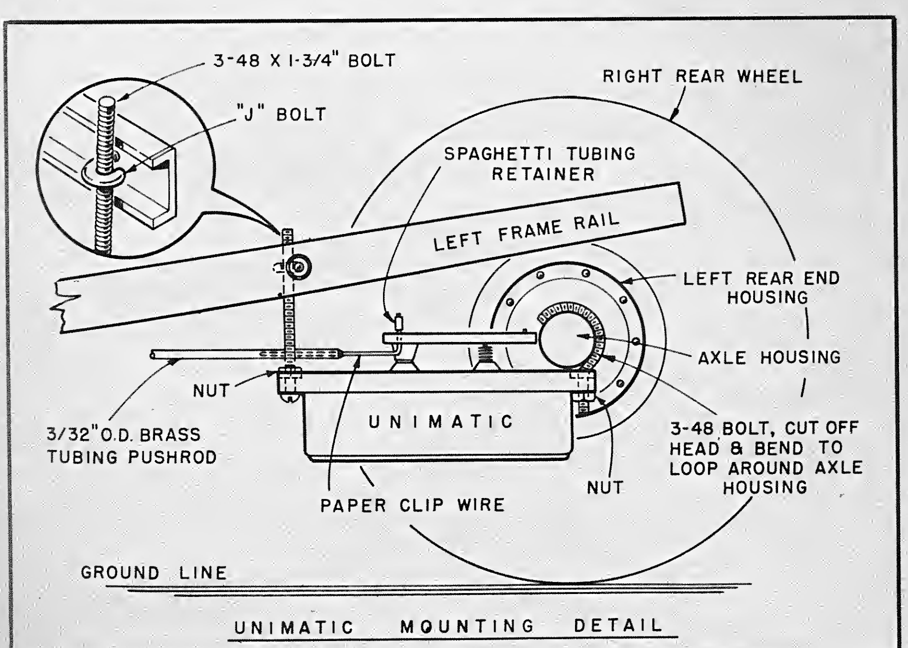
The plastic car (Figs. 10-1 through 10-4): The trend in operable plastic models—autos particularly—to larger sizes and greater realism opens a fertile field to the experimenter. A typical example is the big Lindberg motorized Bobtail T. The example illustrated was made by Aubrey Kochman, and was fully described in the July-August 1963 issue of the *American Modeler*. As this kit comes at the hobby shop, it is equipped with a small electric drive motor, is turnable via a steering wheel, and features a clutch and gear shift just like the real car. Modification to radio control in this instance was the ultimate in simplicity, few changes being necessary.

Radio installation consists of a single-channel receiver. (Relay-type receivers are generally preferred for all vehicles having high-drain devices, though, in this instance, the need is not mandatory.) The receiver works a Graupner Unimatic actuator giving a sequential control — one signal for right, two for left — but with more muscle to steer the vehicle than an escapement, and without the awkward business of having a twisted rubber loop for escapement power. Mounted inside and beneath the frame, adjacent to the rear end (see Fig. 3), the actuator drive arm moves a 3/32" o.d. brass tubing pushrod which connects to a steering bracket attached to the left front brake plate.

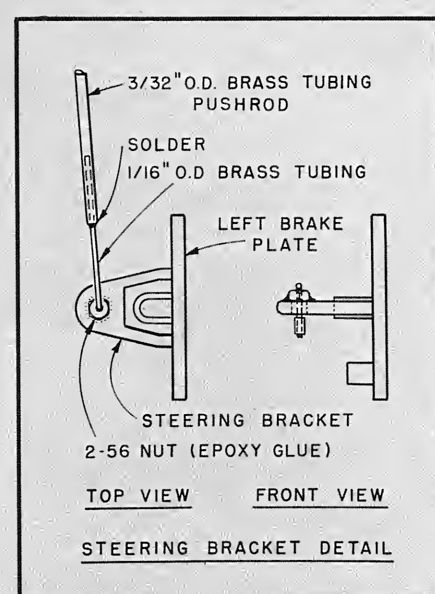
The receiver rests inside the bucket body, and batteries are carried inside the gas tank and under the seat. In this simple conversion — undertaken to determine the feasibility of R/C-ing



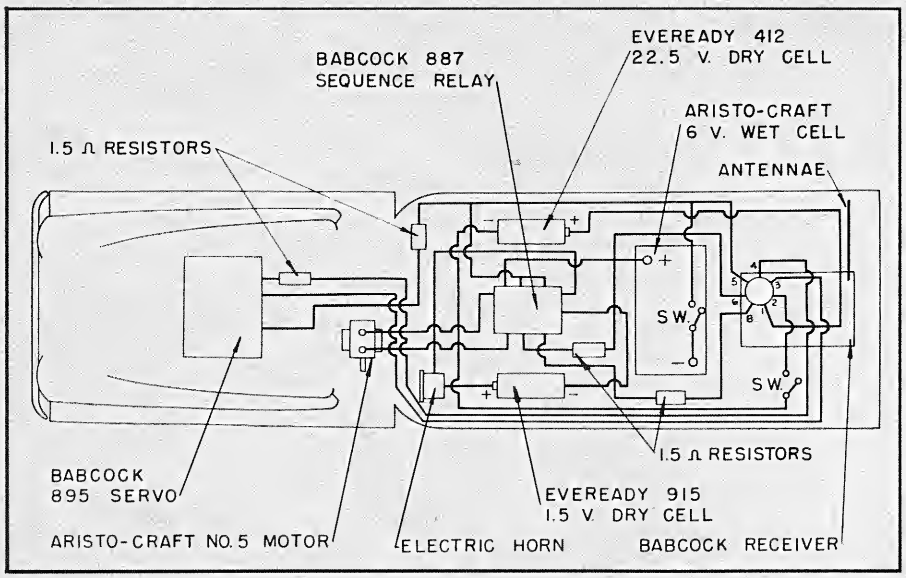
10-2 **Assembled chassis of the Bobtail T, showing changes: (A) Steering pushrod attached to left steering bracket. (B) Brass tubing pushrod. (C) Gearshift and clutch locked for radio control. (D) Unimatic steering machine. (E) Batteries placed inside gas tank (and under seat). (F) Cable and plug for steering machine.**



10-3 **Installation of the Unimatic to frame and axle housing.**



10-4 **Attachment of steering pushrod to steering bracket, which is part of left brake plate.**



10-5 General schematic for a truck (by Walter Musciano). This particular receiver is no longer manufactured, but wiring can be adapted to other appropriate receivers.

Walter Musciano steers his "Green Giant" truck by means of two control box buttons, one for right turn and the other for left.

Trucks are ideal for radio control because the complete installation can be hidden in the body. Here, the designer checks voltage while holding signal on.

a plastic car—the only control is steering. Car speed is not great — if it were, front-end plastic parts would have to be replaced with sturdier metal parts to withstand collisions with obstacles — and there is no available variation in speed, stop-start or reverse. The running gear is purposely separated from the radio gear, with individual on-off switches for each. To subdue electrical "noise" from the drive motor which could bother the receiver, a .01-mfd. ceramic capacitor was soldered across the motor brushes. Changes to the kit included disconnecting the steering wheel gearbox and locking the shift and clutch.

Suggestions for scratchbuilt cars: The very elemental system, both for radio and control, depicted in the Bobtail T can be adapted to other kits and to almost any automotive design of your own. Excellent sources of car outline drawings are the popular auto magazines. These plans can be copied by use of a pantograph, by photostat (some photostaters may ask you to obtain written permission of the publisher for them to make the photostat) or by mechanical drafting. As to the mechanical parts, the well-stocked hobby shop will have an extensive line of electric motors as well as gears and gear trains. While not identified for specific use, these gears, etc., are meant to be used by the hobbyist who is working up his own designs. It is not difficult to prepare your own metal framing to provide any gearing arrangement you require.

Most cars and trucks are simply prepared for steering only, using an appropriate servo or steering machine. Differential arrangements which permit drive wheels to turn at different speeds — for turning — are not usually bothered with. The skilled modeler can, of course, provide a differential. A solution in a simple vehicle is to use one-wheel drive. This is quite adequate.

As with boats, the use of various actuators or multiple channels to yield extra functions solves similar problems. Much can be adapted from boat propulsion and steering systems. While not much has been done yet with fast cars and simultaneous racing, it is quite obvious that existing proportional control outfits, especially those having dual or more channels, will provide the necessary precise steering control, plus variations in motor speeds. Since forward, stop and reverse — often in conjunction with variable motor speeds — are commonly available in marine usage, the identical systems can be applied to automotive designs. Methods of handling high electrical drains are valid for cars as well as for boats. Fig. 10-5 shows a typical schematic for a single-drive-

motor, single-channel system with the truck in the accompanying photos.

Multichannel cars: With independent channels of control, more versatile performance will reward the designer's ingenuity. For an example of what can be done with four channels, the radio-controlled police car shown in schematics and pictures is described with the cooperation of Mr. R. Swindels and *Radio Control Models and Electronics* magazine. For the body he used balsa wood. The wheels are large toy wheels. Only one drive wheel is used, the motor shaft using direct friction drive to a rear-wheel brake drum.

The schematic, Fig. 10-6, is self-explanatory. An interesting point is that the low-drain Mighty Midget electric motor used for steering can be powered through the receiver's relays (Nos. 1 and 2) for left-right without requiring the use of special relays or gadgetry to handle high-drain current. The high-drain drive motor is handled by means of the clever worm gear and cam which closes leaf-type contacts to control polarity to the drive motor for forward, stop, and reverse (Fig. 10-7). (And here again is a good system for a boat.)

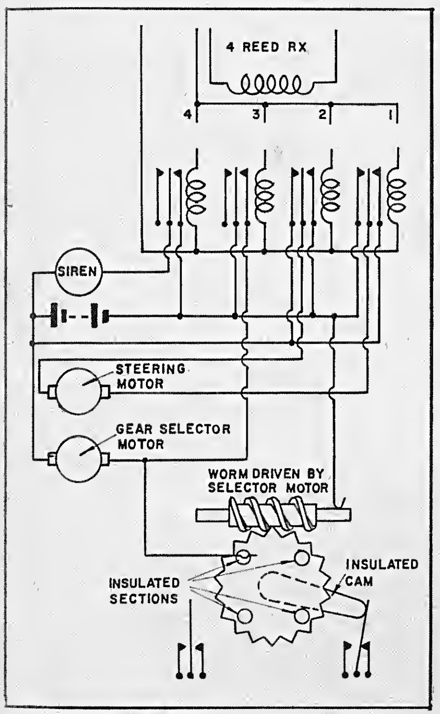
Upon tracing the simple circuitry in Fig. 10-6 you will quickly note how the system works. No. 4 relay, upon closing, operates the siren; Nos. 1 and 2 relays, the steering motor; and No. 3, the gear selector motor. Also note that the gear selector motor has two sources of power, the one mentioned and the other through the brass gear at the bottom of the diagram. What appears to be four holes in the brass gear actually are holes filled with an insulated material known as Araldite (English).

The lead from the gear selector motor to this brass gear ends in a phosphor bronze finger contact which rides the gear face, passing over the insulated round spots. The "holes" are equidistant from each other. Thus, when the contact finger is not resting upon one of the insulated spots, the secondary power source drives the gear selector motor until one of the spots moves under the contact finger. Now, if No. 3 relay is closed momentarily, a power circuit is completed again to the selector motor, which moves the gear far enough for the secondary circuit again to be activated.

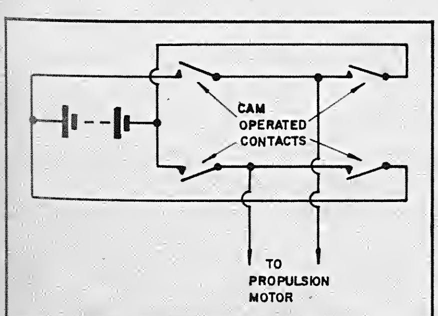
The insulated cam attached to the gear mechanically closes the contacts which control the drive motor. There are four cam positions, two being control positions (contacts closed) and two being neutrals. Operation is in sequence from neutral to forward, neutral again, then reverse. With practice it is possible to skip either forward or reverse.

Fig. 10-7 shows how the current from the 6-volt storage battery (or suitable nickel-cadmium batteries) is reversed by the contacts. Incidentally, a cam on the rear axle of the car operates a pair of spring contacts to operate a blue flashing light on the roof of the car. Fig. 10-8 illustrates the steering system, in which the gear-driven worm actuates the linkage.

Tracked vehicles: The "secret" of the propulsion system for any of these projects is that the drive axle must be divided, each half of the axle being

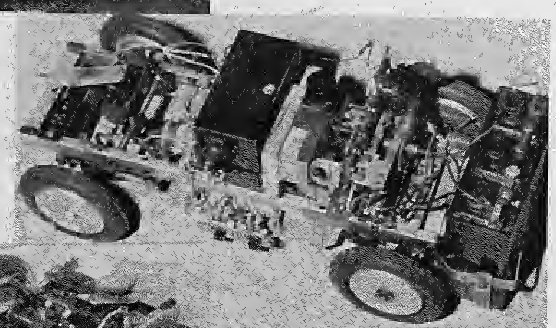


10-6 Schematic for police car, showing use of four channels for horn, steering motor, and gear selector motor which mechanically operates leaf contacts for high-drain drive motor.

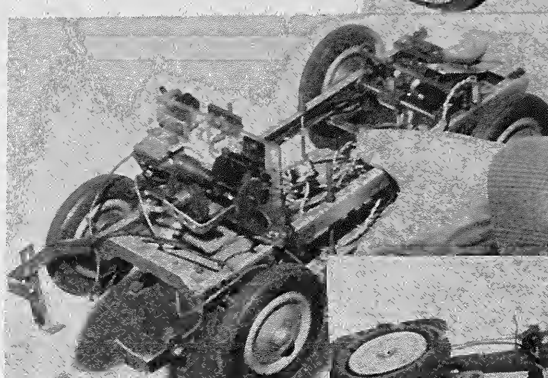


10-7 This schematic should be matched to that shown in Fig. 10-6.

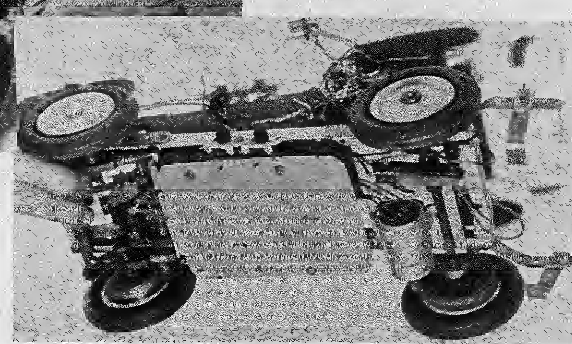
Police car by R. Swindels of England has four-channel control.



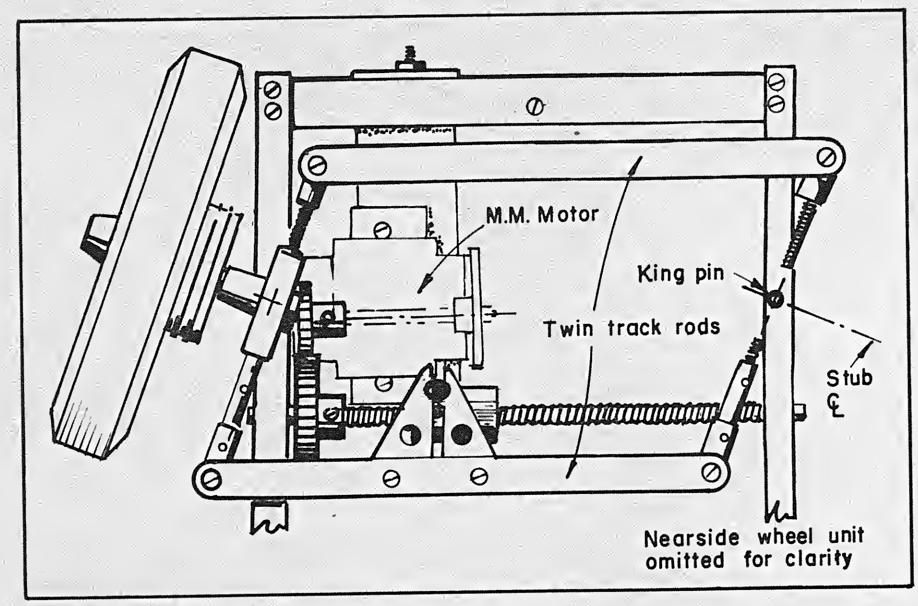
Completely scratchbuilt installation of police car should be compared with the accompanying drawings. In this picture, radio receiver is evident, as well as storage battery at rear.



The worm-gear selector and its drive motor show here, above rear wheels. Schematic and details in Fig. 10-6.



Bottom of police car. Steering motor appears at left, drive motor at right. Note how motor shaft engages drum on right rear wheel by friction.



10-8 Steering detail of police car. Two radio channels enable motor to turn in either direction. Worm gear mechanically operates the twin track rods.

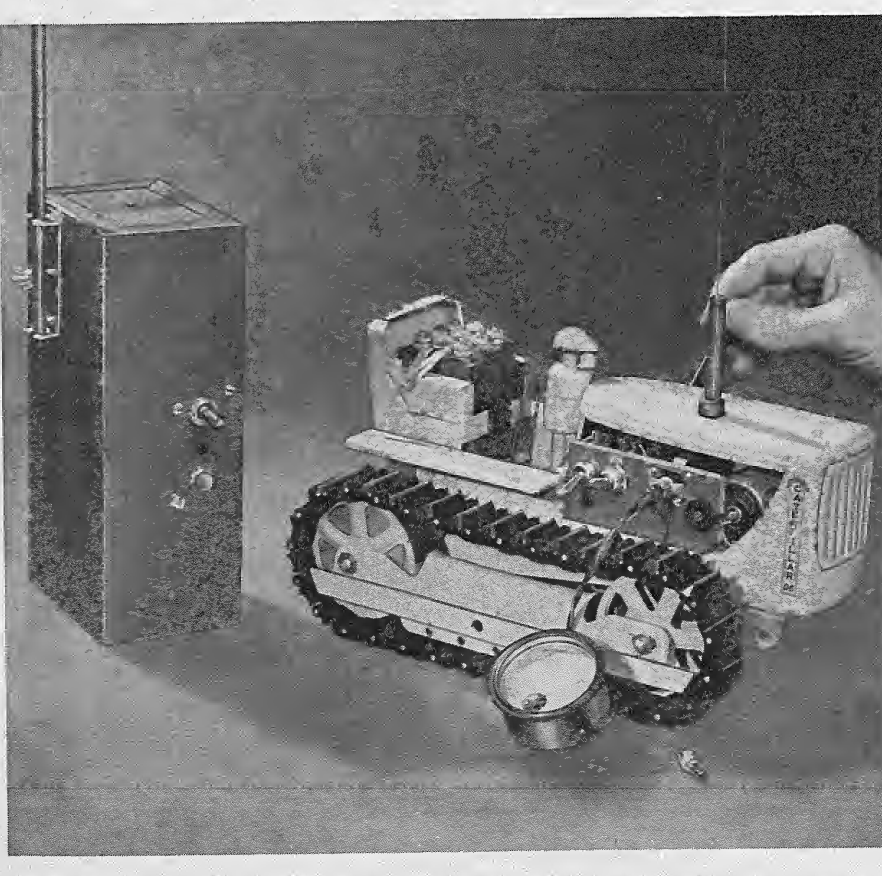
operated directly by gears from its individual electric motor (two required). And again, we can consider the basic systems and problems found in boats.

The Caterpillar tractor shown in Figs. 10-9, 10-10 and 10-11 was developed from a standard toy item by Howard McEntee, radio editor of *American Modeler*, and was published in *Popular Science* magazine. The ingenious use of a single-channel pulse proportional control will appeal to modelers with moderate electronic experience.

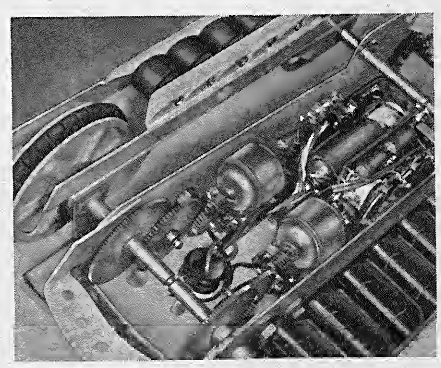
The familiar principles demonstrated in such a system were utilized here with some unique twists. Constant pulsing (equal on-off signals) produces straight-ahead travel; by favoring either the signal-on (longer pulse lengths) or signal-off (shorter lengths) side of the receiver relay by movements of the transmitter control stick or steering knob, either one or the other of the two motors is shut off for turning.

This, of course, produces a realistic jerky steering as would be seen on the full-scale machine. The important thing with drive motors, as usual, is that the receiver relay does not directly close circuits to the high-drain motors. In this case, two appropriate-value relays are located between the receiver relay and the motors. As the receiver pulses, the effect is to hold in these switching relays. Also, in the circuitry between receiver relay and both drive motors is another relay which follows the normal pulsing rate of the receiver relay, but when the pulse rate is stepped up, the resistance-value of this relay causes it to close and hold in. Its contacts are connected in such manner that a switching circuit from forward to reverse is provided for the drive motors.

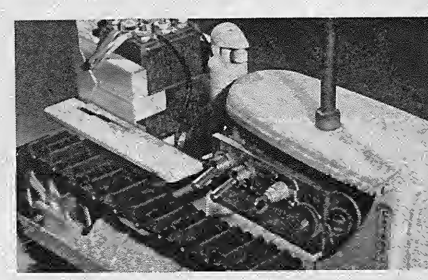
The use of this relay for reversing involves a toy train switching device, sequential in action, which provides (instead of just either a plus or minus polarity) definite contact positions for forward, stop and reverse. To step this switching device, actuating signals consist of momentarily stepping up



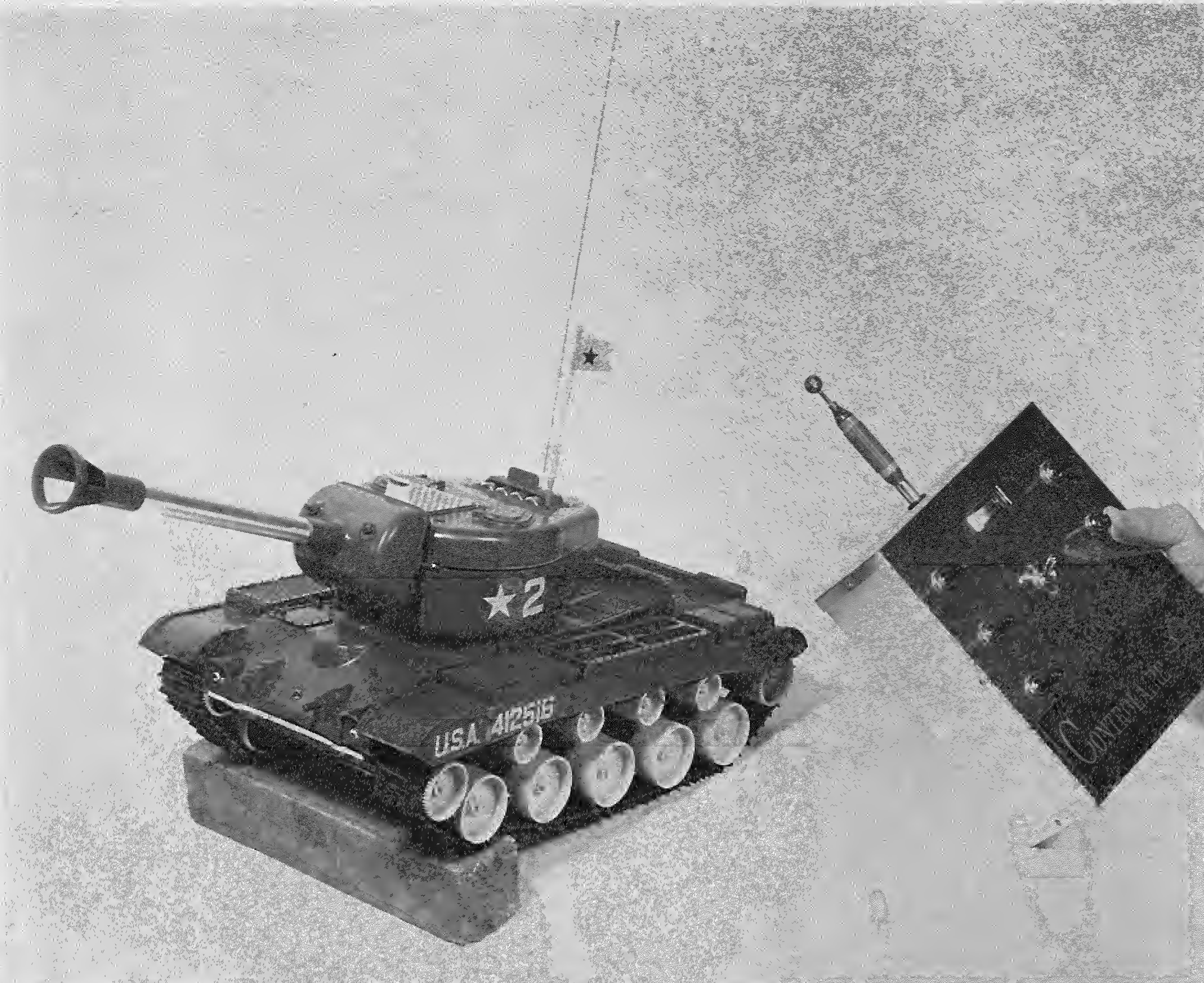
10-9 Howard McEntee's tractor converted from a toy. Single-channel proportional control is used, variations in pulsed signal lengths being used for steering, and an increase in pulse rate for other functions.



10-10 In all tracked vehicles, independent drive is geared to each track. Drive axle is split. In this case, the tractor steers by stopping either motor while the other continues to operate.

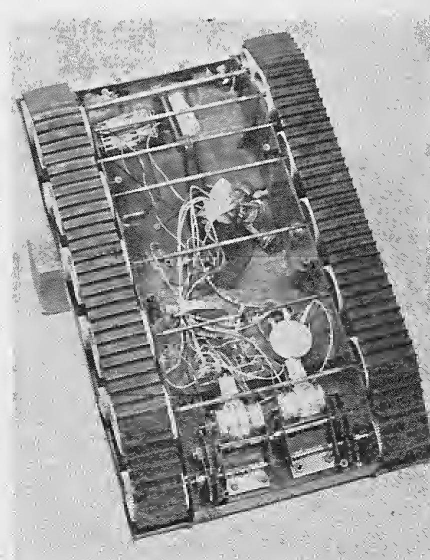


10-11 Power and receiver switches, meter jack and receiver tuning features were organized on a compact panel affixed to side of tractor hood.

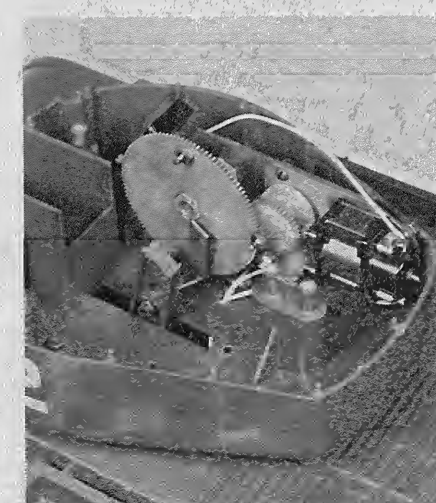


One of two Bulldog tanks converted from Remco toy by Phil Canterra and Kern Bowyer. Using six-channel control, the tanks fought sham battles, firing the toy shells upon signal.

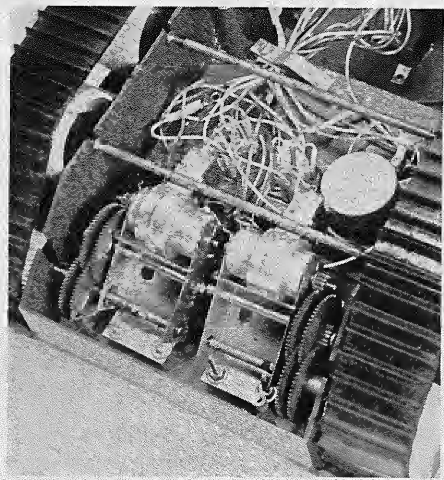
10-12 Inside the Bulldog tank turret, a servo motor and gear train were installed to "load" the cocking spring (part of toy). Four sealed plug-in relays (foreground) were added as part of radio switching arrangement for the two drive motors.



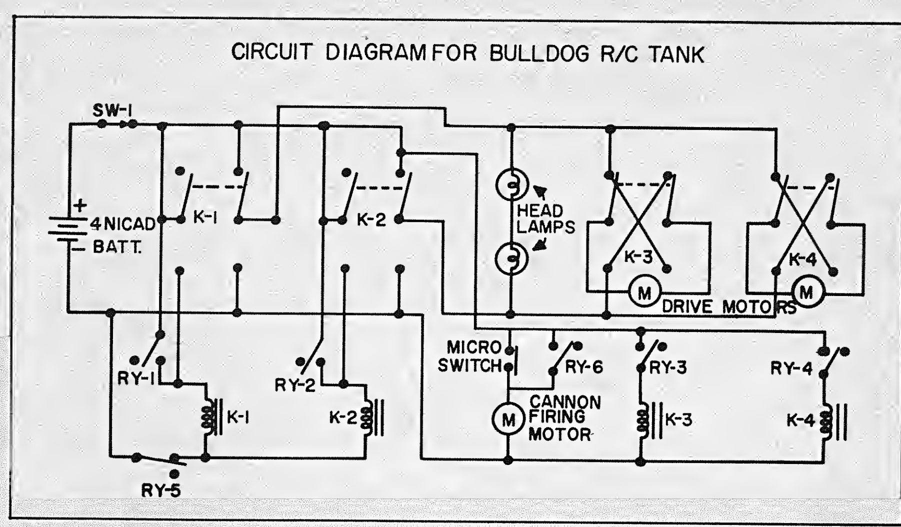
10-13 Bottom of Bulldog tank. Radio receiver and battery pack fit into open area where cluster of plugs appears. Cocking spring and actuating arm can be seen forward; compare with Fig. 10-14.



10-14 Pin on large gear picks up actuating arm (projecting through slot) to tauten cocking spring. Behind the gear (at top) is the microswitch which shuts off the servo-drive motor when the spring is extended, ready for release by radio firing signal.



10-15 One drive motor and gear train came with toy. Second motor is from a second tank. Note that drive axle is split so each motor operates one track. Control pot (above right-hand motor) adjusts faster motor to slower for straight-ahead when no demand signals are sent.



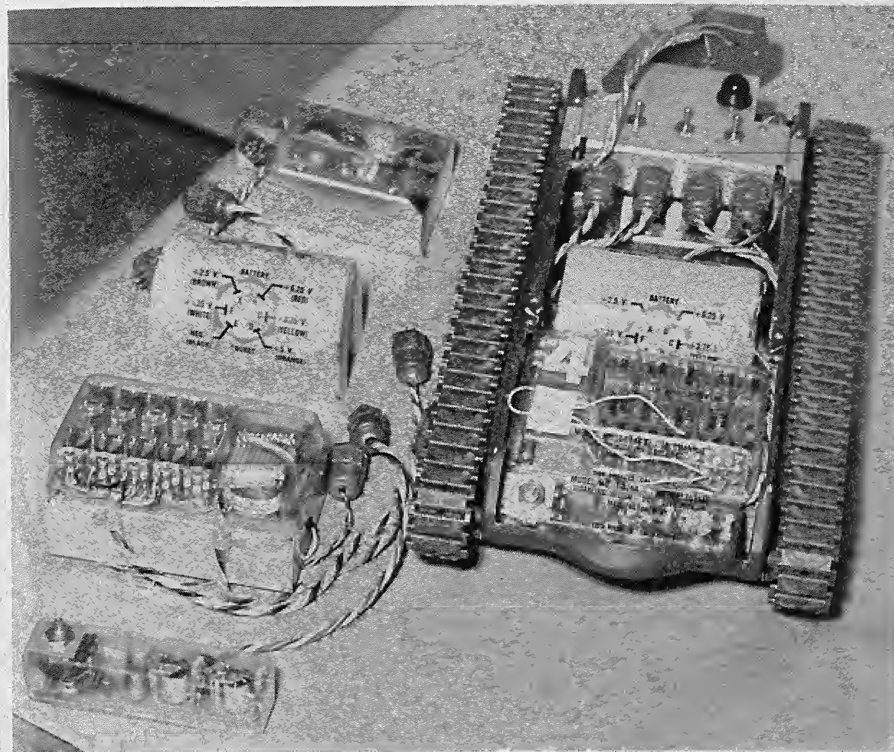
10-16 Receiver power wiring is not shown, as it depends on the unit. All relays are in unenergized position. Key: K-1, forward drive relay; K-2, reverse drive relay; K-3, left turn relay; K-4, right turn; SW-1, main power switch; RY-1, down elevator receiver relay, starts tank forward; RY-2, up elevator receiver relay, starts tank in reverse; RY-3, left rudder relay for left; RY-4, for right; RY-5, low motor receiver relay stops tank; RY-6, high motor, fires cannon by starting cocking motor.

the pulse rate (transmitted signals), returning it to normal rate, stepping it up again — each increase in rate moving the switcher device one more position.

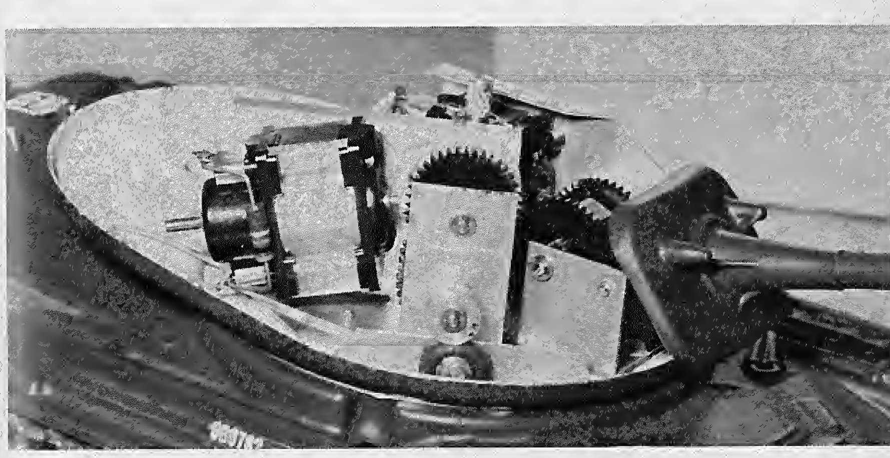
It may be wondered why the two switching relays (for steering) close with pulsing (as signal-on lengths increase). This was achieved by putting resistors across these relays to make them sluggish — therefore, longer pulse lengths are tantamount to a steady signal to hold them closed to make their circuit to whichever drive motor is tied in.

Walker Bulldog tank: The work of Phil Canterra and Kern Bowyer, who made two of these tanks capable of sham battles firing the "shells" that come with the plastic toys (Remco), requires six channels of control. Since the tank comes with one drive motor only, a second tank was purchased in each case to obtain the necessary second electric drive motor with its identical gear train. (One motor for each track.) The drive axle had to be split to provide for independent drive of each track. The problem then became the maintenance of equal r.p.m.'s of both motors for straight-ahead tracking. This was overcome by use of a wire-wound pot (rheostat) in series

10-17 Scale tank built for Army tactical game board using 16 tanks simultaneously. Cannon "fires" light beam; photoelectric cells record "hits" and stop disabled tanks. ↗A: Individual packages plug in: electric eye, 10-channel superhet receiver, nickel-cadmium battery supply, and drive mechanism control. →B: Turret rotates; cannon depresses or lifts. ↘C: Printed-circuit disk provides contacts to wipers in turret.



10-17A



10-17B

10-17C

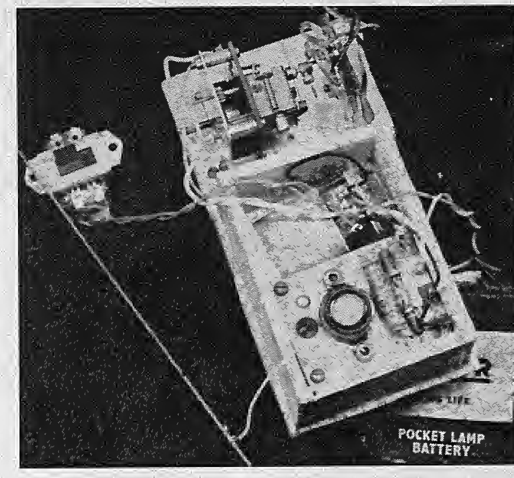
with the faster motor; it is used to adjust the speed of one motor to the other when no turning commands are given. Fig. 10-12 shows the sealed relays added to the circuit to operate the high-drain motors in response to commands through the receiver. Unlike the tractor described previously, either drive motor can be reversed independently of the other so that turns can be made in a tank length.

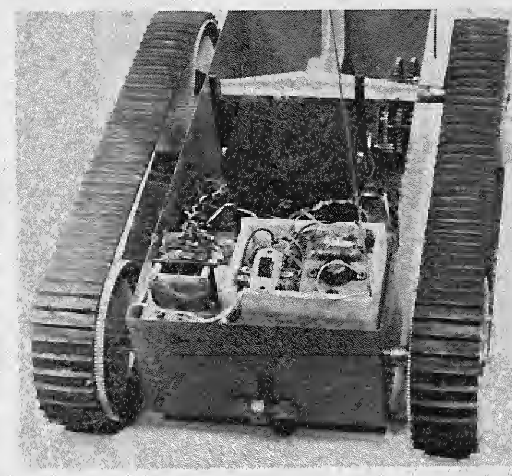
The challenge in this project was cannon-firing. As the tank is sold as a toy, the gun loading and firing mechanism was mechanical by means of levers on the tank body. The gun is cocked by a heavy spring which shows in Fig. 10-13. The hammer and spring are cocked by radio, using an electric drive motor from a Bonner servo and a gear train. (Fig. 10-14.) All the gears except the large metal one came with the servo. The microswitch (right side of the big gear, Fig. 10-12) senses when the motor has fully cocked the weapon. To fire the cannon, the receiver momentarily shorts the open contacts of the microswitch, which starts the cocking motor. When the hammer is released, firing the gun, the motor continues to run until the hammer is cocked again. (For storage of the tank, the battery power is switched off after firing, before the cocking motor can increase spring tension.) Fig. 10-15 clarifies the installation of the drive motors.

It is interesting to note how the controls work with airplane-type transmitter lever switches. Down-elevator starts both drive motors forward simultaneously and turns on the two headlamps shown in Fig. 10-16. Use of left or right rudder causes one tread drive motor to reverse. Low engine stops the drive motors and extinguishes the headlamps. High engine fires the cannon.

Super tank: Figs. 10-17, 17A, 17B, 17C illustrate a truly exotic tank project for use (16 tanks at a time) on a training table with scale landscape. The tanks were built by a hobby manufacturer under army contract. Each tank has an electric light in its cannon and two photoelectric cells under the top of the tread. When a hit is scored, a red light comes on in the destroyed tank, and the tank shuts off its motors and halts. Transmitters are arranged so that the gunner and the tank operator can function independently (radio is superhet). Although these tanks utilize vacuum-formed plastic parts and nylon and vinyl injection moldings, basic features will interest more experienced hobbyists. One such feature is the printed circuit board devised to provide circuits to the turret (left-right) and cannon (up-down) regardless of turret position and movement.

Remotely controlled bulldozer, converted from English toy by Peter Holland, pulls girl in toy fire engine — note transmitter in her left hand.





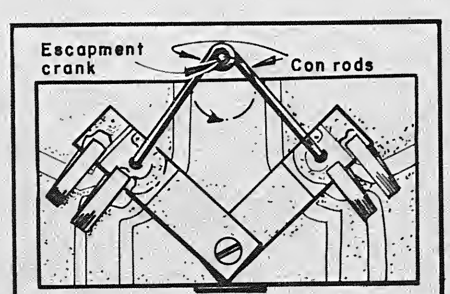
Neat equipment package is shown removed from vehicle and in place, affording two views of spring-type escapement which operates contact fingers over small printed-circuit board for switching purposes.

The tank drive turret and gun drive motors are from Bonner servos, power being five 1.750 mah. voltabloc nickel-cadmium rechargeable batteries. The printed circuit board idea is applicable to all vehicles and machines which have revolving cabs, such as shovels and derricks.

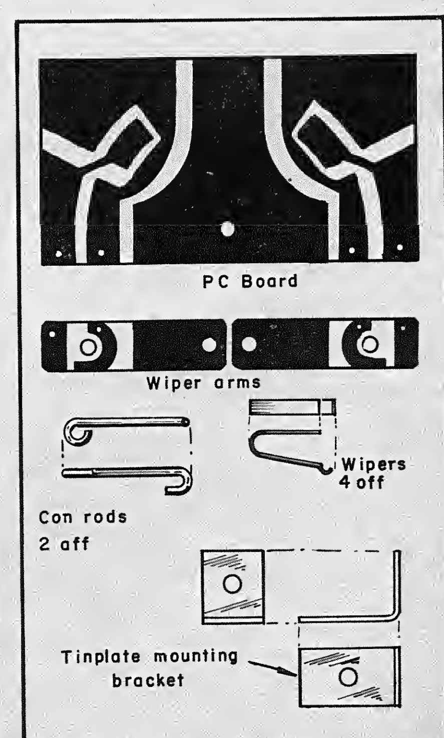
Bulldozer: We are indebted to Peter Holland and *Radio Control Models and Electronics* for the bulldozer pictures and details. What is unique about this "dozer" — adapted from a British toy — is its terrific pulling power and the simplicity of its control system, which is based upon just a single-channel radio and a clockwork escapement (spring-wound type, available in England and by import). As Fig. 10-18 shows, a simple V-shaped contact arrangement is moved over a printed circuit board (Fig. 10-19) by the rotary movement of the escapement crankpin. Fig. 10-20 shows four positions of the contact arm, the two neutrals of the escapement giving alternately forward and reverse of both drive motors, and one motor forward, one reverse, on each of the two signal positions. Small connecting rods soldered to the escapement crankpin move the contact arms (Figs. 10-21, 10-21A).

To avoid interference from "noise" of motors and switcher with the receiver, the motors and switcher were suppressed.

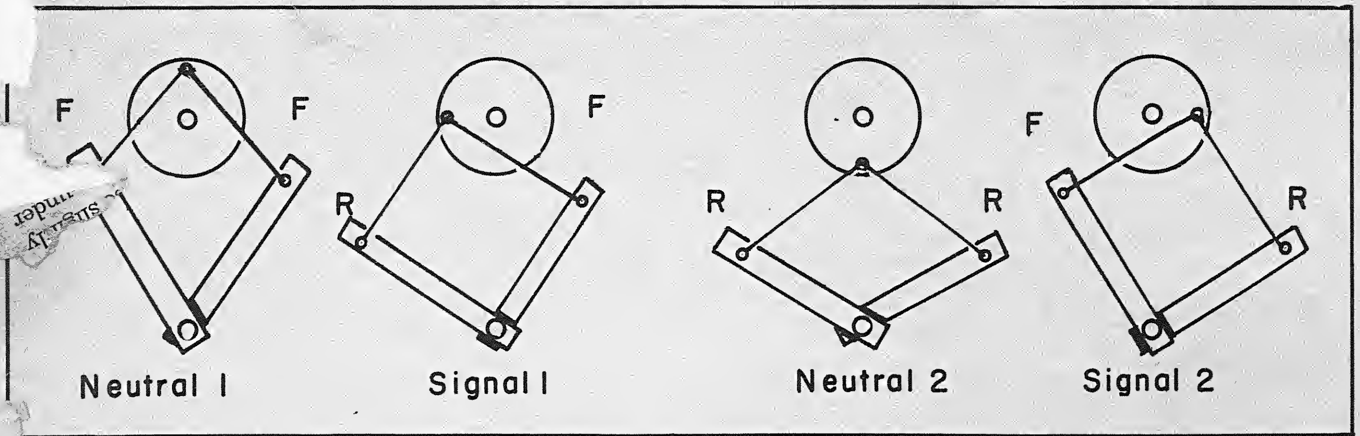
Clamshell crane: An outstanding example of what can be done with standard toy store items is this fully operable clamshell crane developed by a Canadian, J. D. Paterson, who finished the project while with the UN forces in Egypt. Although the tinplate toy is of German origin (Gama), many



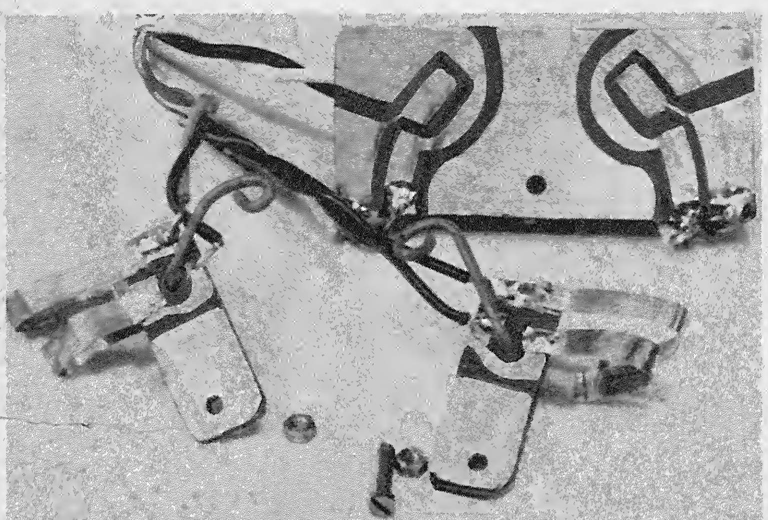
10-18 Escapement crankpin drives wiper contacts through connecting rods.



10-19 Parts used in the escapement-operated printed-circuit switcher.



10-20 **Action of the wiper connecting arms as escapement crankpin changes position with signal.**



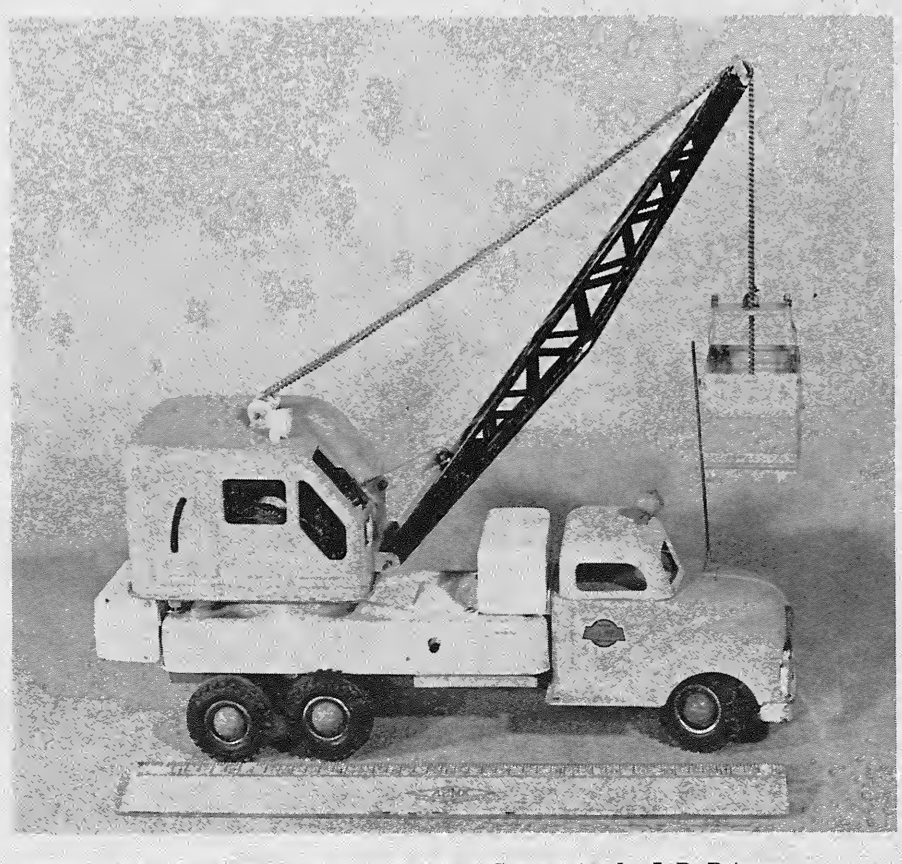
10-21 **Left: The assembled wiper contacts and connecting rods; printed-circuit board in background. 10-21A, above: Complete switcher ready for use.**

more or less similar toys offer similar or somewhat less challenging opportunities.

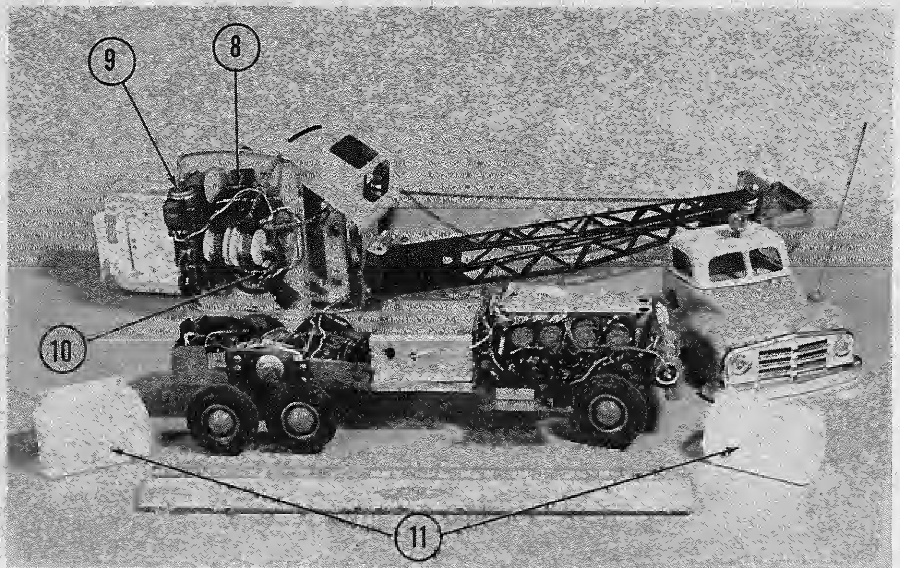
Using eight-channel radio, the vehicle is steerable, with forward-stop-reverse. The bucket can be raised and the cab rotated in either direction. Mr. Paterson used a trimmable-type Bonner Transmite servo for steering but made the other servos himself, using servo amplifier circuitry extracted from magazine articles. (Manufactured servos can be used throughout — if space is a problem, Annco or similarly small servos can be substituted.)

A Japanese electric motor is used for propulsion; it is controlled by a geared-up Mighty Midget electric motor which switches forward-stop-reverse. Another Japanese motor in the cab raises and lowers the bucket. The cab is rotated by a second Mighty Midget motor. Power for these cab motors is brought up from the chassis by means of a disk-operated three-contact brush arrangement beneath the crane cab. Batteries are mounted in boxes — one behind the truck cab, the other behind and below the crane cab.

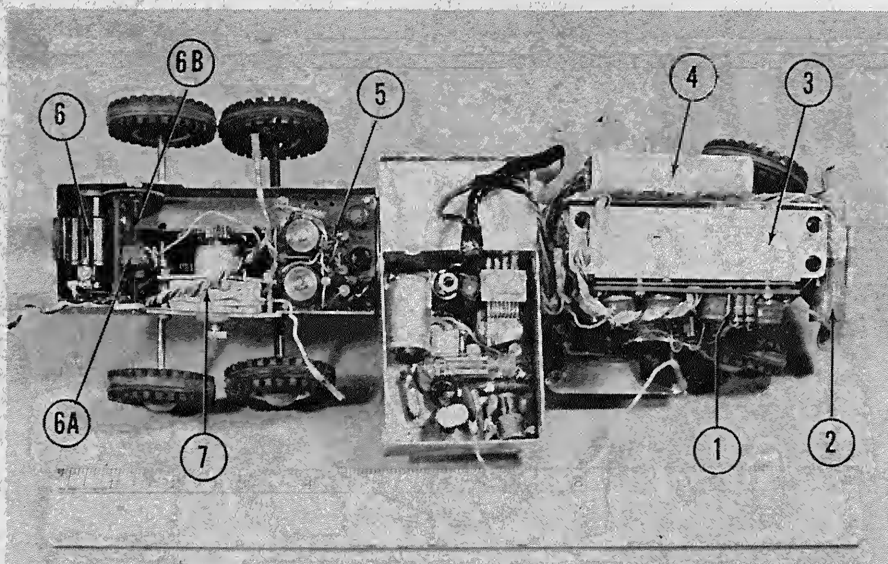
Figs. 10-22 and 10-23 illustrate the



Fully operable clamshell crane adapted from a German toy by J. D. Peterson.



10-22 **(8) Cab rotating motor. (9) Bucket control motor. (10) Brush pickoffs from servo amplifiers (No. 1 in Fig. 10-23). (11) Old IF cans used to hold nickel-cadmium cells.**



10-23 **(1) Servo amplifier for cabin and bucket motors. (2) Filament battery. (3) Steering servo. (4) Radio B battery. (5) Amplifier for motor shown in No. 6. (6) Motor with worm-driven wipers to switch drive motor. (6A) Brush assembly for switcher motor. (6B) Assembly rides on screw. (7) Drive motor: forward, neutral, reverse.**

arrangement. A certain similarity to the police car is evident where the drive arrangement is concerned. At the rear of the chassis, the Mighty Midget motor is geared so that the worm-driven wiper provides switching to the drive motor, thus serving the dual functions of forward-stop-reverse and providing substantial contacts for the high-drain motor drive.

This crane is, perhaps, a rather advanced project considering that its basis is a common toy, but it does indicate many practical ideas which can be extracted by the experimentally minded reader who will find applications to other types of vehicles as well.

Submarines: While not a ground-operated vehicle, the submarine is so specialized that we've elected to discuss it in more detail in this chapter. It is generally assumed that subs are enormously complicated. Surprisingly, they are not necessarily complicated in their systems approach, but they do require specialized operational techniques. As with other projects, a great deal can be done with single-channel control, or a finer degree of functions control can be provided by means of multichannel receivers.

Model submarines do not usually completely submerge, in the sense that they run deep under water. Normal operation calls for periscope-depth running, achieved by ballasting and trimming the vessel for a waterlogged condition when at rest (Figs. 10-24, 10-24A). So arranged, the sub will float with deck awash when not moving or when on low motor. With more speed, the sub inclines its nose slightly downward until the deck is under water, where it is trimmed with radio control to maintain depth — a ticklish operation, from all reports. Since negative bouyancy is not quite encountered, a control failure will allow the craft to surface to its waterlogged condition.

Some builders have utilized controllable diving planes. Some have found the use of these planes created a too-sensitive response and had to be much smaller than full-scale practice would indicate. Water ballasting is not required, although the Nautilus shown (Figs. 10-25, 10-25A), ironically using just one-channel radio, does pump in water through the torpedo tube to fore and aft trim tanks, ejecting it again through the periscope. This does complicate the installation, requiring a water pump and drive motor with attendant switching for the pump circuit. The advantage is that the vessel can be normally trimmed less deck awash for high-speed running, depending upon the water ballasting ability to trim it closer to a negative bouyancy condition for diving and underwater running.

It will be noted in all these cases that the receiver antenna is never under water, thus providing uninterrupted control. Actually, true underwater radio control is possible for the well-versed electronics man, but the author knows of only one such instance in the popular hobby field.

There is, however, one method of causing a sub to run deep, and this is done by cam programing. In a simple form the cam would be spring-escapement-driven or clock-powered to operate controls mechanically. Or it could be a printed circuit disk, as typified on some servos, with finger contacts to switch circuits to one or more control motors. ITC—one of the larger manufacturers of operable plastic models and toys — has used cam programing not only on a sub (not radio-controlled) but on scale cars as well. With cam programing, the sub is not under radio control while deeply submerged. Radio operates the craft on the surface and to begin the dive. Once under water, radio control ceases, while the cam — which can be interchangeable for different programs — takes the boat through simple maneuvers such as turn, straight ahead and surface.

The vessel would be trimmed with deck awash at rest so that flotation would be insured. Forward speed alone could be depended upon to